A PENGUIN SPECIAL

Edward Glover

# THE PSYCHOLOGY OF FEAR AND COURAGE

A PENGUIN SPECIAL 1940

# THE PSYCHOLOGY OF FEAR AND COURAGE

BY

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# AUTHOR'S NOTE

NOTE.—Chapters I to IV were originally prepared for purposes of broadcasting. An abbreviated version of the section on "Rumour" was broadcast on July 16th, 1940, in the "Calling all Women" series. Portions of the other chapters were broadcast on July 25th, 1940, under the title "Talking it Over: the Handicap of Temperament." I am indebted to the B.B.C. for permission to include the material here.

E. G.

# CONTENTS

*Real knowledge*, for example, is one of the best antidotes to unreal fear. *Useful action* is also an excellent preventive, and *vigorous preparation to meet real danger* will enormously reduce unreal fear. The strength of a common purpose will do the rest. Knowledge, a common purpose, and preparedness for action. These are the remedies for faintness of heart in the face of danger.

22

Now as to preparation. You may recall that when Napoleon was asked how he was always able to give an instant decision in a crisis, he replied: "Because I constantly prepare every detail in advance." Here is a discipline you can readily cultivate. Always make a point of knowing beforehand *exactly* what you are going to do in an air raid; whether you find yourself in house, street, train, bus or shelter. Have it word perfect.

23

A stray crowd packed into a cinema is likely to panic at the cry of "Fire." There are no common bonds between the people concerned; and there are no leaders. Each one is for himself.

34

Already we have the advantage that we are fighting not only for our lives and homes but for the immemorial cause of human liberty. But that is not enough. Provided we are united with our leaders in a common effort, real danger will never sap our morale. The greatest danger to our morale is unreal fear.

36

Fear, suspicion and hate may damage our morale, but they cannot destroy it so long as our will to victory draws strength from those deep cementing instincts that bind human beings together. However hackneyed the adage: "United we stand, divided we fall," it is still the most profound of psychological truths.

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Take, for example, the ideas of communism and fascism, which obviously overstep the barriers of nationalism. A moment's reflection will show that these ideas do not unite nations. On the contrary, unless the peoples concerned are deprived of freedom of speech, thought and political power, they cause acute dissension rather than unity. They disintegrate.

121

one of the greatest flaws of the Nazi political philosophy is its stupendous over-estimation of the significance of the State. Compared with the organisation of an individual, the State is an almost amorphous mass.

122

But if you take this view you have, whether you know it or not, committed yourself deeply to the worship of truth. For if you want children's minds to develop, you must not poison them with important illusions. You must let their minds be free to observe and judge. By the same token you have committed yourself to defending any man's right to shoot off his mouth in a pub or to be told what's what about the war.

126

There are five main aims to which everyone in this kingdom can subscribe: to preserve one's life, home, family and country from either physical or mental violence, to defend cherished institutions from violence, to protect the weak, dependent and infirm, to preserve truth and to uphold law.

The great majority are moved by simple and humane emotions, and by the desire to respect and live at peace with their neighbours. But if these simpler people really want to win this war, they must become more *aware* of their own fundamental values.



always borrow inspiration from the Greek poets. We can say with Euripides:

> "What then is Wisdom? What of man's endeavour?
>
> . . . . . . . . . . . . . . . . . . . . .
>
> To stand from Fear set free, to breathe and wait,
> To hold a hand uplifted over Hate.
> And shall not Loveliness be loved for ever?"*

* *Bacchae*. (Gilbert Murray's translation.)


TY
D'S

ILLUSTRATION NO. 8.

The house in the upper photograph had a Government steel table shelter in a downstairs room and was blown up to reproduce the effect of a heavy bomb falling near. The whole house collapsed, burying the shelter under débris. In the lower photo the shelter can be seen still intact. It would have been possible for anyone in the shelter to get out unaided.

National Archives
HO197/24

# Morrison Shelters in Recent Air Raids.

A report of Ministry of Home Security experts on 39 cases of bombing incidents in different parts of Britain covering all those for which full particulars are available in which Morrison shelters were involved shows how well they have stood up to severe tests of heavy bombing.

All the incidents were serious. Many of the incidents involved direct hits on the houses concerned a risk against which it was never claimed these shelters would afford protection. In all of them the houses in which shelters were placed were within the radius of damage by bombs; in 24 there was complete demolition of the house on the shelter.

A hundred and nineteen people were sheltering in these "Morrisons" and only four were killed. So that 115 out of 119 people were saved. Of these only 7 were seriously injured and 14 slightly injured while 94 escaped uninjured. The majority were able to leave their shelters unaided.

CD 2333

[redacted]

# HOME OFFICE

CD/SA 12
Copy. No 5.

## OFFICE OF THE CHIEF SCIENTIFIC ADVISER

### A COMPARISON BETWEEN THE NUMBER OF PEOPLE KILLED PER TONNE OF BOMBS DURING WORLD WAR I AND WORLD WAR II

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**BOMB SIZES**

=> ≈ 175 kg

For World War II the average bomb weight was between 150 - 200 kg. (R.C. 268, Table 6), whereas for World War I the majority of bombs were 12 or 50 kg.

---

**TABLE 5**

**Relative safeties in World War II deduced from population and casualty distribution**

| | In the open | Under cover | In shelter |
|---|---|---|---|
| Population exposure | 5% | 60% | 35% |
| Location people killed | 19% | 62% | 19% |
| Relative safety | 72% | 20% | 10% |
| RELATIVE DANGER! | | | |

(1) A house about $3\frac{1}{2}$ times as safe as in the open.
(2) A shelter about twice as safe as a house.

---

Table 6 also shows the location of killed which is implied by each of the possible population exposures. The only evidence available on this point is that, for the day raid on June 13th, 1916, in which the total number killed was 59, 69.5% of the people killed in the City were in the open.

SECRET.

W.P.(G)(41)7. COPY NO. 62

January 15th, 1941.

# WAR CABINET.

## AIR RAID SHELTER POLICY.

Memorandum by the Minister of Home Security.

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6. Shelter in the home: The Anderson shelter was originally intended for indoor use but for a number of reasons including the danger of fire an outdoor variant was adopted. Experience has shown that the objections to the indoor use of the Anderson or somewhat similar shelter are not so serious as was thought and two designs have been produced which can be erected indoors without support. These new types, although they may give slightly less protection than a well covered Anderson shelter out of doors, would fill the needs of a large section of the public, especially the middle class. One design allows the use of the shelter as part of the furniture of the room.

7. I regard shelters of this type as of the first importance and wish to provide them on a big scale. Each shelter will use over 3 cwt. of steel and will allow at a pinch two adults and one to two children to sleep inside. For an outlay of about 65,000 tons of steel, as a first instalment, I could therefore produce 400,000 shelters with accommodation for at least 1,000,000 persons. I should wish to complete such a programme within the first three months of production and thereafter at a similar or increasing rate. From enquiries I believe that manufacture can be arranged provided steel is supplied and if the Cabinet approves my policy I shall require their direction that the steel be made available.

10. Conclusions.

I ask for a general endorsement of the policy I have outlined in this paper and in particular for the agreement of my colleagues:

(i) that proposals for building shelters of massive construction should be rejected;

(ii) that steel should be made available to carry out the programme outlined in paragraph 7 for the provision of steel shelters indoors;

(iii) that the limit of income for the provision of free shelter for insured persons should be raised from £250 to £350 per annum.

H.M.

MINISTRY OF HOME SECURITY.

January 15th, 1941.

*Printed for the War Cabinet.* *May* 1941.

MOST SECRET. Copy No. 58

W.P. (G) (41) 44.
*May* 5, 1941.

**TO BE KEPT UNDER LOCK AND KEY.**

**It is requested that special care may be taken to ensure the secrecy of this document.**

**WAR CABINET.**

# AIR RAIDS ON LONDON, SEPTEMBER–NOVEMBER 1940.

*Memorandum by the Home Secretary and Minister of Home Security.*

*Framed buildings.*

Most valuable information has been gained on the effects of bombs on framed buildings. Such buildings are practically immune to anything but a direct hit. Blast damage from bombs outside is usually confined to windows and internal partitions. Even parachute mines falling immediately outside the building or exploding on the roof produce negligible damage to structure or floors.

*Relation of Casualties to Bombs Dropped.*

From a knowledge of the number of bombs dropped and the casualties occurring in different boroughs, some idea can be gained of the effectiveness of bombs in producing casualties. The number of casualties per bomb varies widely from 1·59 in the least to 6·94 in the most populated boroughs, but it follows closely the apparent densities of population as shown in figure 1. The number of casualties per bomb is roughly a twelfth of the number of persons per acre, and the number of deaths per bomb about 1/60th of the number of persons per acre. From this it can be deduced that the mean distance at which injury from a bomb is likely to occur is 35 ft., and that at which the bomb is lethal is 15 ft.

The casualties per bomb in Central London fell steadily from an average of 3·7 in September to 2·7 in October and 1·7 in November. This corresponds to the considerable fall in population in most of the boroughs concerned.

*Conclusion.*

We may now say that we have a good general understanding, both qualitative and quantitative, of the effects of bombs on buildings and on cities. New types of bombs, particularly heavier bombs, may be used, but we can anticipate no startling change in the effects apart from increase in minor damage. With bombing of the present type the results of our work are to show that in urban areas, such as that of the County of London, *for one ton of bombs approximately* 10 *houses will be destroyed or will need pulling down.* 25 *more will be temporarily uninhabitable, and another* 80 *will be slightly damaged.* 80 *people will be made temporarily homeless and* 35 *will lose their homes permanently.* 25 *people, mostly among the latter category, will be wounded, the greater part of them slightly, and* 6 *will be killed or die from wounds.*

~~CONFIDENTIAL~~

DEPARTMENT OF THE ARMY TECHNICAL MANUAL | TM 23-200
DEPARTMENT OF THE NAVY | OPNAV INSTRUCTION 03400.1B
DEPARTMENT OF THE AIR FORCE | AFL 136-1
MARINE CORPS PUBLICATIONS | NAVMC 1104 REV

# CAPABILITIES OF ATOMIC WEAPONS (U)

**Prepared by**
**Armed Forces Special Weapons Project**

**DEPARTMENTS OF THE ARMY, THE NAVY AND THE AIR FORCE**

***REVISED EDITION NOVEMBER 1957***

~~CONFIDENTIAL~~

*c. Indirect Blast Injury.*

(1) *General.* Indirect blast casualties result from burial by debris from collapsed structures with attendant production of fractures and crushing injuries, from missiles placed in motion by the blast wave, or from fire or asphyxiation where individuals are prevented from escaping the wreckage.

(2) *Personnel in structures.* A major cause of personnel casualties in cities is structural collapse and damage. The number of casualties in a given situation may be reasonably estimated if the structural damage is known. Table 6–1 shows estimates of casualty production in two types of buildings for several damage levels. Data from Section VII may be used to predict the ranges at which specified structural damage occurs. Demolition of a brick house is expected to result in approximately 25 percent mortality, with 20 percent serious injury and 10 percent light injury. On the order of 60 percent of the survivors must be extricated by rescue squads. Without rescue they may become fire or asphyxiation casualties, or in some cases be subjected to lethal doses of residual radiation. Reinforced concrete structures, though much more resistant to blast forces, produce almost 100 percent mortality on collapse. The figures of table 6–1 for brick homes are based on data from British World War II experience. It may be assumed that these predictions are reasonably reliable for those cases where the population is in a general state of expectancy of being subjected to bombing and that most personnel have selected the safest places in the buildings as a result of specific air raid warnings. For cases of no prewarning or preparation, the number of casualties is expected to be considerably higher. To make a good estimate of casualty production in structures other than those listed in table 6–1, it is necessary to consider the type of structural damage that occurs and the characteristics of the resultant missiles. Glass breakage extends to considerably greater ranges than almost any other structural damage, and may be expected to produce large numbers of casualties at ranges where personnel are relatively safe from other effects, particularly for an unwarned population.

*Table 6–1. Estimated Casualty Production in Structures for Various Degrees of Structural Damage*

| | Killed outright | Serious injury (hospitalization) | Light injury (No hospitalization) |
|---|---|---|---|
| 1–2 story brick homes (high explosive data): | *Percent* | *Percent* | *Percent* |
| Severe damage | 25 | 20 | 10 |
| Moderate damage | <5 | 10 | 5 |
| Light damage | ------ | <5 | <5 |
| Reinforced-concrete buildings (Japanese data, nuclear): | | | |
| Severe damage | 100 | ------ | ------ |
| Moderate damage | 10 | 15 | 20 |
| Light damage | <5 | <5 | 15 |

*Note.* These percentages do not include the casualties which may result from fires, asphyxiation, and other causes from failure to extricate trapped personnel. The numbers represent the estimated percentage of casualties expected at the maximum range where the specified structural damage occurs.

Personnel in a prone position are less likely to be struck by flying missiles than those who remain standing.

6–3

*Table 6–2. Critical Radiant Exposures for Burns Under Clothing*

*(Expressed in cal/cm² incident on outer surface of cloth)*

| Clothing | Burn | 1 KT | 100 KT | 10 MT |
|---|---|---|---|---|
| Summer Uniform | 1° | 8 | 11 | 14 |
| (2 layers) | 2° | 20 | 25 | 35 |
| Winter Uniform | 1° | 60 | 80 | 100 |
| (4 layers) | 2° | 70 | 90 | 120 |

6–4

# CUE

# FOR SURVIVAL

**OPERATION CUE**

**A. E. C. NEVADA TEST SITE**

**MAY 3, 1955**

A REPORT BY THE

FEDERAL CIVIL DEFENSE ADMINISTRATION

# EFFECTS OF NUCLEAR WEAPONS

BY HAROLD L. GOODWIN,
*Director, Atomic Test Operations, FCDA*

A great deal of information has been released over the past several years on the effects of atomic explosions, yet many of these effects are still poorly understood by the general public. For that reason, the principal effects of a nuclear explosion are reviewed, with a brief discussion of factors of particular importance to civil defense.

This entire section is based on informaton available in published sources. There is a widespread but erroneous view that most information on the effects of nuclear explosions is classified, and hence is not available to the general public. Information that exists only in classified form generally is information which deals with refinements of weapons effects. A considerable amount of gross information on any major effect is available in a number of publications.

The best reference in this field is still the basic handbook, *The Effects of Atomic Weapons.* Despite the fact that this useful work was first published in 1950, queries daily to the Federal Civil Defense Administration indicate that it has not been widely studied or understood. A thoughtful reading will be of value to any person with civil defense responsibility. A revision, now in process, may be issued in the next few months.



The time of travel of the shock wave is not generally understood by many persons. The concept of "duck and cover," which would still be of great value in case of attack without warning, is based on the comparatively large time interval between the burst and arrival of the shock wave at a given point.

It takes several seconds for the shock wave of a nominal bomb to reach a point 2 miles from the burst. A person who moved promptly at the first light of the detonation would have time to get under or behind a convenient piece of furniture, or other protection. At greater distances there would be even more time.

This time lapse between the detonation and arrival of the shock wave was graphically demonstrated to persons watching from the observer areas in the Test Site. The detonation takes place, a phenomenon without sound from the viewpoint of the observer. So much time elapses between the detonation and arrival of the shock wave that observers sometimes forget that the shock wave is on its way and the loud bang of its arrival finds them unprepared. Persons are frequently startled and have even been pushed off balance by the shock wave. The pause between a lightning flash and the thunder is comparable.

The question may be asked, how will one know when a burst has gone off if the sound does not arrive for some time? The answer is that the light from the explosion is its own warning.

# BIOMEDICAL EFFECTS OF THERMAL RADIATION

BY DR. HERMAN ELWYN PEARSE, *Professor of Surgery at the University of Rochester. Consultant to several Government departments, notably the Atomic Energy Commission's Division of Biology and Medicine. Consultant to the Armed Forces Special Weapons Project*

After the Bikini test, I was asked to go to Japan as a consultant for the National Research Council to survey the casualties in Nagasaki and Hiroshima. Being a surgeon, I was greatly impressed with the magnitude of the medical problem from burns and wounds very largely caused by flying missiles. They constituted roughly 85 percent of the casualties in Japan.

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In Japan it was an August day, the people were lightly clothed, and they were out in the open.

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Then we observed the healing of the wounds, and we found again that the wounds healed in the same manner as those that we had produced in the laboratory. There was some difference in these lesions from the ordinary burns of civil life, but I would predict, from what I learned from experiments, that the difference is on the good side. The burns look worse; they are often charred, but they may not penetrate as deeply, and the char acts as a dressing, nature's own dressing. The scab solidifies, and the healing process goes on under that scab, after which the scab is sequestrated, and the healed surface is revealed beneath.

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I didn't care what happened to the fabrics; I wanted to know what happened to the man under the fabric. So we conceived this idea, that the important factor in studying clothing was what happened under the clothing; how it shielded the animal with cloth of different composition, weight, texture, weave, and color. We have made a great many studies both in the laboratory and in the field on this problem of the protective effect of clothing....

For example, if you have 2 layers, an undershirt and a shirt, you will get much less protection than if you have 4 layers; and if you get up to 6 layers, you have such great protection from thermal effects that you will be killed by some other thing. Under 6 layers we only got about 50 percent first degree burns at 107 calories.

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If we can just increase the protection a little bit, we may prevent thousands and thousands of burns.

... For example, to produce a 50-percent level of second-degree burns on bare skin required 4 calories. When we put 2 layers of cloth in contact, it only took 6 calories. But separate that cloth by 5 millimeters, about a fifth of an inch, and it increases the protective effect 5 times. The energy required to produce the same 50-percent probability of a second-degree burn is raised up to 30 calories. So if you wear loose clothing, you are better off than if your wear tight clothing.

**144**

UR-261

Health and Biology



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# STUDIES ON FLASH BURNS: THE PROTECTION AFFORDED BY 2, 4 AND 6 LAYER FABRIC COMBINATIONS

by:

George Mixter and Herman E. Pearse

Division: Special Programs

Division Head: H. A. Blair

Section: Flash Burn

Section Head: H. D. Kingsley

Submitted by: Henry A. Blair,
Director

Date of Report: 6/4/53

# STUDIES ON FLASH BURNS:

# THE PROTECTION AFFORDED BY 2, 4 AND 6 LAYER FABRIC COMBINATIONS

by

George Mixter, Jr., M. D. and Herman E. Pearse, M. D.

## ABSTRACT

Fabric interposed between a carbon arc source and the skin of Chester White pigs increased the amount of thermal energy required to cause 2+ burns. For the 2, 4 and 6 layers of fabric studied this increase was 3.6, 38 and over 104 cal/cm$^2$ respectively when the inner layer of fabric was in contact with the skin. Separation of the inner layer from the skin by 5 mm increased the protective effect of the 2 layer combination from 7.4 to 29 cal/cm$^2$, provided the outer layer was treated for fire retardation. If the outer layer was not so treated, sustained flaming occurred which in itself added to the thermal burn.

## INTRODUCTION

In the past, work in this laboratory has been directed toward a study of flash burns in unshielded skin. It is well known from the atomic bombing in Japan that this type of burn was modified by clothing. A laboratory analysis of the protective effect of fabrics against flash burns was begun (5) by shielding the skin with a few representative fabrics and their combinations.

1. 2 Layers
   a. light green oxford
      knitted cotton underwear
   b. light green oxford (HPM)
      knitted cotton underwear
2. 4 Layers
   olive green sateen
   thin cotton oxford
   wool-nylon shirting
   knitted cotton underwear
3. 6 Layers
   olive green sateen
   thin cotton oxford
   mohair frieze
   rayon lining
   wool-nylon shirting
   knitted wool underwear

5. Morton, J. H., Kingsley, H. D., and Pearse, H. E., "Studies on Flash Burns: The Protective Effects of Certain Fabrics", Surgery, Gynecology and Obstetrics, 94, 497-501 (April 1952).

# THE EFFECTS OF THE ATOMIC BOMBS AT HIROSHIMA AND NAGASAKI

## REPORT OF THE BRITISH MISSION TO JAPAN

PUBLISHED
FOR THE HOME OFFICE AND THE AIR MINISTRY BY
HIS MAJESTY'S STATIONERY OFFICE
LONDON
1946

Photo No. 17. HIROSHIMA. Typical, part below ground, earth-covered, timber framed shelter 300 yds. from the centre of damage, which is to the right. In common with similar but fully sunk shelters, none appeared to have been structurally damaged by the blast. Exposed woodwork was liable to " flashburn." Internal blast probably threw the occupants about, and gamma rays may have caused casualties. See paragraph 40.

Photo No. 18. NAGASAKI. Typical small earth-covered back yard shelter with crude wooden frame, less than 100 yds. from the centre of damage, which is to the right. There was a large number of such shelters, but whereas nearly all those as close as this one had their roofs forced in, only half were damaged at 300 yds., and practically none at half a mile from the centre of damage. See paragraph 41.

# AIR WAR AND EMOTIONAL STRESS

## Psychological Studies
## of
## Bombing and Civilian Defense


Irving L. Janis

The RAND Corporation



First Edition

NEW YORK • TORONTO • LONDON
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1951

# CHAPTER 2
# EMOTIONAL IMPACT OF THE A-BOMB

## UNPREPAREDNESS OF THE POPULATION

At both Hiroshima and Nagasaki, disaster struck without warning. Whether intended so or not, an extraordinarily high degree of surprise was achieved by both A-bomb attacks. At the two target cities, prior to the bombing, there had been relatively little anxiety about the threat of heavy B-29 raids. When the planes carrying the A-bomb arrived over their targets, the population was almost completely unprepared. At the time, not even a light air raid was expected. People were caught at home, at work, out on the city streets, calmly going about their usual daily affairs.

When the first A-bomb was dropped, on August 6, 1945, very few residents of Hiroshima were inside air-raid shelters. An all-clear signal from a previous alert had sounded less than half an hour earlier and the normal routine of community life had resumed. Shortly after eight in the morning, when the explosion occurred, the working-class population was arriving at the factories and shops. Many workers were still out-of-doors en route to their jobs. The majority of school children, along with some adults from the suburbs, were also outside, hard at work building firebreaks as a defense against possible incendiary raids. Housewives, especially in middle-class families, were at home, preparing breakfast. Only a few minutes later, their flaming charcoal stoves were to create hundreds of local fires, adding to a general conflagration of such intensity that even if the assiduous labor of Hiroshima's school children had been completed, the fire storm still would have been beyond control.

At Nagasaki, three days later, the populace had heard only vague reports about the Hiroshima disaster. Here again, people were at

work in factories and offices, tending their homes, engaging in their normal daily activities. A few hours earlier a raid alert had been canceled; before the raid signal could be repeated, the bomb had already exploded. Only 400 people out of a population of close to a quarter of a million were inside the excellent tunnel shelters that could have protected some 75,000 people from severe injury or death.

It is generally recognized that the element of surprise was an important factor contributing to the unprecedented casualty rates at Hiroshima and Nagasaki. Many of those who were exposed to lethal gamma radiation, struck down by flying debris, or trapped in collapsed buildings would not have been killed if they had been warned in time to flee to the outskirts of the city or if they had been in adequate shelters. Thousands of people who were out-of-doors or standing in front of windows would have been protected from incapacitating flash burns if they had been under any sort of cover.[1]

Whether or not they suffered severe injury, those who survived the explosion were also affected by the element of surprise in quite another way. The absence of warning and the generally unprepared state of the population undoubtedly augmented the emotional effects of the disaster. "I was just utterly surprised and amazed and awed." This brief remark, by a newspaper reporter who was living in Nagasaki at the time of the disaster, epitomizes the way in which survivors described the terrifying events to which they were so suddenly exposed.

Of great importance in the predispositional set of the population is the fact that there was not a state of readiness to face danger or to cope with the harsh exigencies of a major catastrophe. The stage was well set for extreme emotional responses to dominate the action. It is against this background of psychological unpreparedness that the emotional impact resulting from the atomic disasters should be viewed.

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[1] USSBS Report, *The Effects of Atomic Bombs on Hiroshima and Nagasaki*, U.S. Government Printing Office, Washington, D.C., 1946.

Time from flash to blast = 4 sec at 1 mile:

Although exceedingly brief, this time interval was apparently sufficient for executing some forms of protective action.

A substantial proportion of the respondents in Hiroshima and Nagasaki reported having reacted immediately to the intense flash alone, as though it were a well-known danger signal, despite the fact that they were unaware of its significance at the time. A number of them said that they voluntarily ducked down or "hit the ground" as soon as the flash occurred and had already reached the prone position before the blast swept over them. A Nagasaki housewife told about being suddenly frightened by "something shining in the sky" as she was entering her home; she managed to run into her bedroom "to hide" before the blast wave reached the house and shattered all the windows. A worker in Nagasaki reported that he was out in the street waiting for a streetcar when the big "flash-like electric spark" occurred; he promptly dashed into a nearby public shelter and was inside by the time the blast wave struck. These examples indicate that the atomic flash was not merely an impressive visual stimulus but also, in some cases at least, a danger signal evoking semi-automatic overt responses. The examples culled from the interviews serve to amplify one of the incidental observations mentioned in the USSBS medical report: "Japanese claim that in some instances persons were able to shield their faces with their hands between the time the flash was seen and the time the heat wave reached them."[8]

In the instances cited so far, the prompt action proved to be of a highly adaptive character in that it minimized exposure to the secondary heat and blast waves, preventing burns and concussive blows. The interviews also indicate that this was not always the case. The opportunity to minimize the danger was sometimes missed because the individual remained fixed, staring at the place where he saw the flash, or because the prompt action proved to be wholly in-

[7] Los Alamos Scientific Laboratory, *The Effects of Atomic Weapons*, U.S. Government Printing Office, Washington, D.C., 1950.

[8] USSBS Report, *The Effects of Atomic Bombs on Health and Medical Services in Hiroshima and Nagasaki*, U.S. Government Printing Office, Washington, D.C., 1947.

appropriate. The following is an example of the latter type of nonadaptive behavior: A young woman in Nagasaki stated that "when I saw the flash of light in the sky I thought it was an incendiary so I started running around looking for water to put it out." It was in the midst of this futile activity that the concussion wave arrived and bombarded her with flying debris.

From the above discussion, it is apparent that some of the survivors immediately perceived the flash as a danger signal. It also appears that for those who were not located near the center there was an opportunity to take protective action that could reduce injuries from the secondary heat wave and from flying glass, falling debris, and other blast effects. It is noteworthy that some survivors evidently failed to make use of this opportunity, as is to be expected when there has been no prior preparation for it.

In a later chapter on the problems of civil defense, we shall have occasion to take account of these findings, since they suggest that casualties in an A-bomb attack might be reduced if the population has been well prepared in advance to react appropriately to the flash of the explosion.

Under such conditions, rapid, uninterrupted flight would generally be the most adaptive response. In the absence of precise, detailed observations of escape behavior, one cannot make an adequate evaluation of the degree of emotional control exhibited by the survivors. To stop and to attempt to extricate others in the face of a rapidly spreading conflagration would sometimes be tantamount to futile sacrifice of one's own life. We cannot be sure, therefore, that those who fled without stopping to help others were behaving impulsively, since we cannot exclude the possibility that they may have been acting on the basis of a realistic appraisal of the danger situation. Our information is too incompletè to permit any fine judgments to be made; from what little is available, it would be unwarranted to conclude that there was a sizeable frequency of inappropriate, negligent, or asocial behavior merely because some instances of abandonment have been reported.

Although Hersey's case material offers little support for the notion that overt panic states were widely prevalent at Hiroshima, it does suggest that under certain local hazardous circumstances, when a large number of people were crowded together, there may have been outbreaks of excited, disorganized group behavior with antisocial consequences. One clear-cut instance of this kind is mentioned by Hersey:

> As Mr. Tanimoto's men worked, the frightened people in the park pressed closer and closer to the river, and finally the mob began to force some of the unfortunates who were on the very bank into the water. Among those driven into the river and drowned were Mrs. Matsumoto of the Methodist school, and her daughter.[30]

A single reference to disorganized group behavior also occurs in one of the eyewitness accounts from Nagasaki: A child who was seven years old at the time of the disaster reports that there was "almost a panic" among the adults in a neighborhood shelter when planes flew over on the night after the bombing.

> The ones near the entrance started pushing to get inside more. They shouted, "Get inside! Move back farther! Let us in, there'll

[30] Hersey, *op. cit.*

> be another flash!" They were so scared! And the ones inside yelled when they got squeezed, because their burns hurt. [Satoru Fukabori's story in *We of Nagasaki*][31]

It should be mentioned that these two incidents are the only examples of group panic or near-panic that were found after a thorough search of all published accounts of the atomic disasters. All the original USSBS interviews from Hiroshima and Nagasaki were also examined. No indications that would suggest the occurrence of mass panic behavior were found in those interviews. A sizeable proportion of the A-bombed survivors do mention that they ran away from the burning city after the explosion, but, in the sparse accounts of themselves and of the people whom they saw, there are no references to excited, uncontrolled behavior that could be characterized as overt "panic."

In only a handful of cases, out of more than a hundred interviewed, is there any allusion to distraught or impulsive behavior that had occurred at least momentarily. The four most extreme examples have already been quoted under "Fear and Terror Reactions," page 21. To these, only a few more could be added, all of which involve only momentary impulsive actions that were immediately brought under control. For example, one woman said that she had been so frightened by the blast that she had already run out of her destroyed house before realizing that her children were left behind, whereupon she immediately returned to the ruins and rescued them.

In contrast to the high percentage of respondents who reported having experienced feelings of fear, less than 10 per cent referred to any action carried out "without knowing what I was doing" or to any other kind of behavior that might remotely imply temporarily disorganized activity.

Obviously, the above negative evidence with respect to panic behavior cannot be taken at face value. There is no way of knowing to what extent the respondents were distorting, suppressing, or repressing their memories of the actual events of the disaster. Since no direct questions were asked about overt actions, some of the

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[31] Nagai, *op. cit.*

number of psychiatric patients admitted to hospitals and clinics, nor was there any increase in the incidence of suicides or alcoholic intoxication. For most indicators of mental disorder, the statistics show a decrease rather than an increase. For example, cases of attempted suicide among women (recorded by the police in England and Wales) decreased by 32 per cent during the year of the air blitz (1941), as compared with the prewar rate. Figures on juvenile delinquency, on the other hand, registered a rise during the war years, but, according to Titmuss, these data are not a suitable index of either juvenile or adult neurosis.

The findings cited by the various British writers are based on material obtained from a large number of psychiatrists and medical psychologists, including observers with widely different clinical and theoretical approaches to psychiatric problems. Their methods of investigation ranged from brief psychiatric examinations for purposes of large-scale statistical tabulation to intensive case studies of small groups of patients. Despite the diversity of diagnostic criteria used, there is high agreement that the type of air attacks to which London and other English cities were subjected during World War II did not produce a sizeable increase in major psychiatric disorders.

The available information on psychiatric air-raid casualties among German civilians is consistent with the British findings. At the end of the war in Europe, the Medical Team of the USSBS sent a questionnaire to German psychiatrists and directors of psychiatric institutions. The "universal reply" to the questionnaire was that "neither organic neurologic diseases nor psychiatric disorders can be attributed to nor are they conditioned by, the air attacks."[8]

A parallel survey of relevant specialists on psychosomatic disorders in Germany revealed some definite wartime trends (which will be discussed later in this chapter), but what is relevant here is the general conclusion: ". . . in view of the tremendous exogenous stimuli which offered a fertile ground for the development of psychosomatic complaints, the relative infrequency of the development

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[8] USSBS Report, *The Effect of Bombing on Health and Medical Care in Germany,* U.S. Government Printing Office, Washington, D.C., 1945.

admissions for diseases of the nervous system. The statistics from several cities suggest that during periods of bombing there may have been a slight increase in the number of cases with organic and functional psychosis, but this trend is not consistently borne out. Detailed results are presented from only two psychiatric hospitals. One of the hospitals, in Yokohama, showed that there was a *marked increase* in the number of admissions for schizophrenia, general paresis, and other psychoses during May, 1945, the month during which the city received its most severe bombing. The other psychiatric hospital, in Kobe, showed that during the months of severe bombing attacks there was a *decline* in the number of admissions for psychosis and for all other neuropsychiatric disorders. Although some of the Japanese hospital statistics lend themselves to interpretations about possible causal factors, the evidence is not adequate for ascertaining whether bombing produced any significant changes in the incidence of neuropsychiatric cases. In general, the statistical data from Japan do not contradict the observations reported from England and Germany.

The absence of psychiatric casualties following the one air raid on American territory—the Pearl Harbor attack on December 7, 1941—has been described by Weatherby.[11] On the day of the attack, no patients with war neurosis were brought to the hospital that normally served a majority of American troops stationed at Oahu. During the two weeks following the attack, the number of psychiatric admissions was no greater than during the two weeks preceding the attack.

In evaluating the evidence on psychiatric effects of air warfare, it is necessary to recognize that the information is far from complete and that many of the observations are unsystematic and impressionistic in character. Moreover, the statistical studies of psychiatric casualty rates have been criticized on various grounds as underestimating the actual number of psychiatric casualties to be expected among a civilian population exposed to heavy air raids. Vernon[12]

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[11] F. E. Weatherby, "War Neuroses after Air Attack on Oahu, Territory of Hawaii, Dec. 7, 1941," *War Med.*, Vol. 4, 1943, pp. 270–271.

[12] *Loc. cit.*

If the population of a target city is unprotected, the vast majority would undergo traumatizing experiences of personal involvement in an A-bomb attack. It should be recognized, therefore, that the adequacy of civil defense preparations designed to increase the physical safety of the population have a direct bearing on the emotional impact of an atomic disaster. If a target city cannot be warned and evacuated before an attack is launched, if the residents cannot reach adequate shelters, and if well-trained civil defense teams are not available to carry out the essential operations of disaster control, the devastating consequences cannot be counted solely in terms of the inordinate toll of dead and injured people. The less adequate the physical protection of the population, the higher the incidence of emotional shock and disorganized behavior. In an atomic war, such reactions on a mass scale might become a crucial deterrent to national recovery.[3]

To a very large extent, the *morale* of the survivors of an A-bomb attack will be determined by the effectiveness of civil defense measures. During the air blitz against England it became increasingly apparent that the availability of welfare and relief facilities can play a decisive role in minimizing feelings of bitterness, suspicion, free-floating hostility, and other adverse morale effects.

> The rest centres, the feeding schemes, the casualty services, the compensation grants, and the whole apparatus of the post-raid services both official and voluntary occupied this role of absorbing shock. They took the edge off the calamaties of damage and destruction; they could not prevent, but they helped to reduce, a great deal of distress. Like the civil defence services, these schemes encourage people to feel that they were not forgotten. They render much less likely (in William James' phrase) an "unguaranteed existence," with all its anxieties, its corruptions and its psychological maladies.[4]

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[3] The reassurance value and morale-building effects of various military defense measures are greatly in need of detailed study. It should be clear to the reader that the present study has not gone into military plans for active and passive defense of potential targets.

[4] R. M. Titmuss, *Problems of Social Policy.* His Majesty's Stationery Office, London, 1950.

not very useful to assume that "panic" will necessarily be the most probable response.

"Panic" is often used by both popular writers and social scientists as a colorful term to designate any collective dread that is judged to be inappropriate to the occasion. For example, the reactions following the *Invasion from Mars* radio program, which are commonly referred to as panic, consisted mainly of the following: Many people, having tuned in during the middle of the program, heard newscasts and announcements to the effect that some sort of invasion had occurred and that evacuation was necessary; they immediately felt anxious, notified others in their vicinity, phoned members of their families, and in some cases went so far as to carry out the instructions to evacuate.[7] Evidently there were relatively few in the radio audience whose behavior could be characterized as manifestly irrational or antisocial. For most participants, the panic consisted primarily in their reacting to a *false* emergency warning in a manner which, by and large, would have been appropriate for a *genuine* emergency warning, without first checking on its authenticity.

Although "panic" is an extremely ambiguous term, the image it usually brings to mind is that of a wildly excited crowd behaving in an impulsive, completely disorganized fashion, each person abandoning all social values in a desperate effort to save himself. From the available literature on extreme fear reactions, it appears that this sort of behavior rarely occurs unless (1) there is an obvious physical danger which is immediately present (e.g., a raging fire only a few feet away) and (2) there are no apparent routes of escape. Hence, panic, in the limited sense of the term, is likely to be evoked by an A-bomb attack primarily in the area where the disaster actually occurs, e.g., among those who are trapped by the general conflagration within the city. In places which are not affected by the explosion, including the cities which are potential targets for the next attack, there is far less danger of a serious outbreak of overt panic. That is to say, there is a strong likelihood that with appropriate psychological preparation such reactions can be prevented.

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[7] H. Cantril, *The Invasion from Mars*, Princeton University Press, Princeton, N.J., 1940.

the Federal Civil Defense agency should have responsibility for releasing basic information and that state and local defense officials should develop an intensive educational program for their own areas.

It can be assumed, therefore, that as part of the general preparedness program there will be some form of educational program on atomic warfare devised to reach the American public. Thus, while one sector of the general population will be receiving intensive special training for the type of civilian defense functions discussed in the preceding chapter, the remainder of the population will also be receiving instruction designed to prepare them to cope with A-bomb emergencies.

## OBJECTIVES OF A PUBLIC EDUCATIONAL PROGRAM

That there will be enormous problems involved in attempting to carry out a successful program of mass education becomes apparent as soon as one considers the quantity and the content of the elementary material to be learned. The following is a brief outline of typical items of information which would be essential for the average civilian to know if he is to maximize his chances for survival following an atomic explosion:

1. Appropriate actions during an A-bomb alert: the best place to go if one is at home, at work, out in the open; the best position of the body for protection against blast effects; etc.
2. Appropriate emergency responses to the bright flash of an A-bomb explosion in case of a surprise attack: what the flash will look like; how to avoid injury from the secondary heat wave and the concussion wave; what to do immediately after the concussion wave has passed.
3. Ways of averting fire hazards: how to escape from burning buildings; what to do if one's clothes catch fire; where the safest places of refuge are if one is caught inside the fire area; how the potential fire hazard can be reduced if one

is at the periphery of the explosion; under what conditions one should evacuate to escape from a developing conflagration.

4. Essential precautions against radiological hazards: how to tell whether or not one should remain indoors; how to find an uncontaminated area; which kinds of food are safe to eat and which are unsafe; decontamination rules concerning removal of exposed clothing, scrubbing of exposed parts of the body, etc.
5. Probable location of emergency facilities: nearest medical-aid station if at home or at work; where food, clothing, shelter, and supplies can be obtained after escaping from the disaster area.

The above items pertain only to *individual* survival. If the average person is to be adequately prepared to give the most elementary kind of aid to members of his family and to others, there are many more topics to be included—such as, how to extract a person from beneath debris without injuring him unnecessarily; how to carry injured persons; how to give emergency first aid for burns, cuts, broken bones.

Certain kinds of technical information might also be included. For instance, in order to reduce confusion about the large number of "do's" and "don'ts" concerning radiological hazards—and to prevent the undesirable extremes of irrational indifference and excessive fear—it will probably be helpful to give some basic information about the nature of the radioactivity emitted by an A-bomb explosion. Perhaps by presenting the material pictorially and graphically, so as to reify the radioactive particles, people will come to regard them as a familiar and real part of the physical world. Conceivably, this material might be supplemented by training in certain types of technical "know-how."

It may turn out to be feasible to mass-produce various kinds of radiological safety equipment at a relatively low cost: detection meters, film badges to register total amount of personal exposure, gas masks or respirators, canvas suits and boots, etc.

~~RESTRICTED~~ for PRO 93/89

3 OCTOBER 1963



# HOME OFFICE

# SCIENTIFIC ADVISER'S BRANCH

CD/SA 116

## RESEARCH ON BLAST EFFECTS IN TUNNELS

### With Special Reference to the Use of London Tubes as Shelter

by F. H. Pavry

### Summary and Conclusions

The use of the London tube railways as shelter from nuclear weapons raises many problems, and considerable discussion of some aspects has taken place from time to time. But - until the results of the research here described were available - no one was able to say with any certainty whether the tubes would provide relatively safe shelter or not.

This research, consisting of a series of model experiments, has demonstrated that the risk from blast in the tubes would be less than the risks above ground. The results are considered to be consistent enough to provide a good estimate of full-scale conditions, and reliable enough to be used as a basis for Home Office shelter policy regarding the London tube railways.

### Introduction

When the Advisory Group on Structural Research for Civil Defence was formed in 1957, the Chairman recommended that a study of the effects of blast on tunnels should be one of the main research projects. The relevant paragraphs of his proposals(1) for a research programme were:-

> "In any consideration of tunnels as shelter the crucial problem is the entry of blast, either through existing openings or from a crater formed by a ground-burst bomb. It is particularly important to know if the collapse of a tunnel by earth shock would prevent the blast from entering it, and also whether the collapse would provide a seal against the entry of water from the crater. It is probable that some data could be derived from model experiments using H.E. charges. But it is for consideration whether the results would be so conclusive that the behaviour of full-size tunnels when damaged by megaton weapons could be forecast with the confidence that a major shelter programme would demand."

At the second meeting(2) the Group agreed that model experiments with H.E. charges would be worthwhile, and that the Atomic Weapons Research Establishment (A.W.R.E.) should carry out this research, which has now been accepted by the Advisory Group as successfully completed. A summary record of the progress follows.

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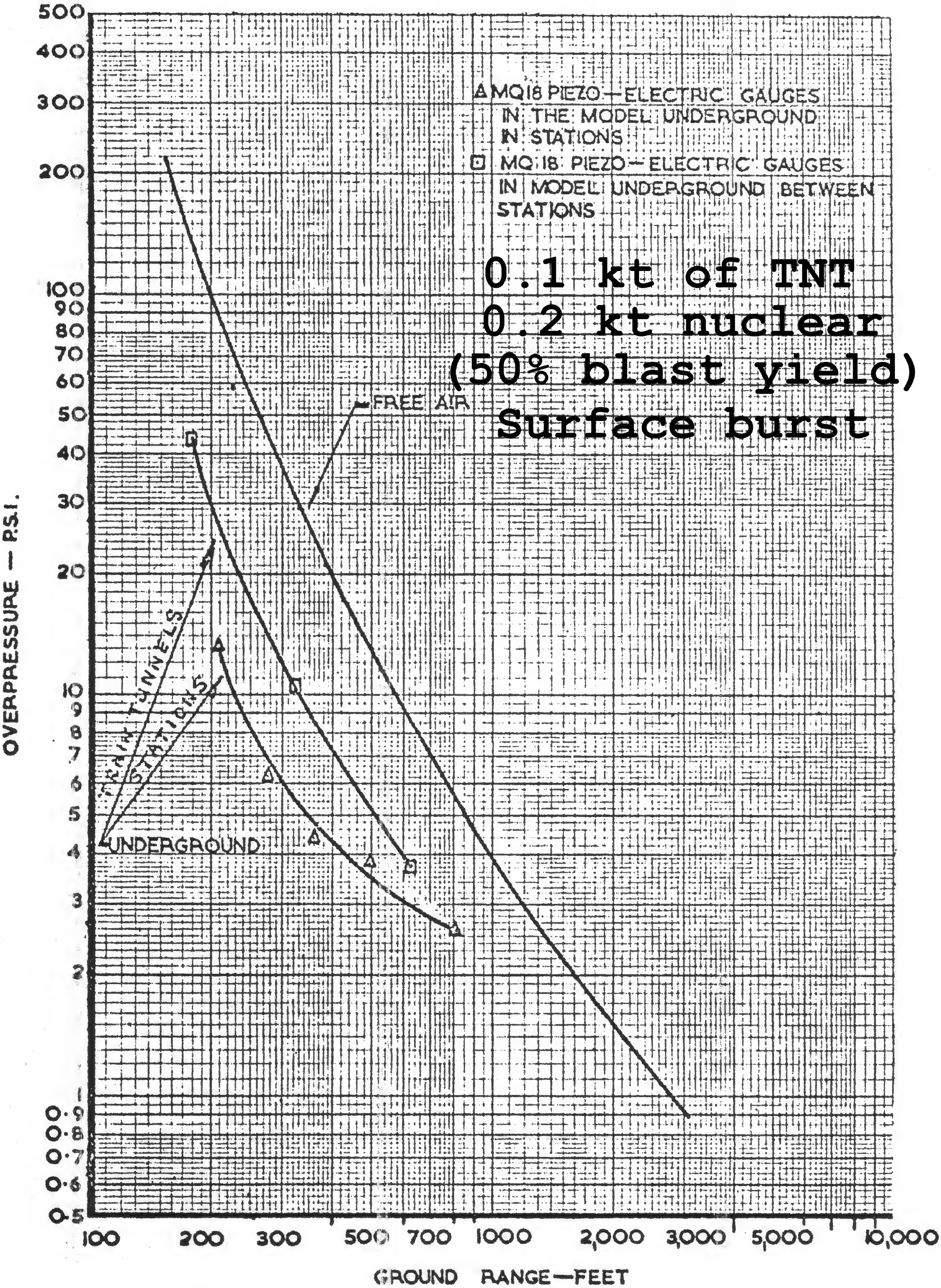
100 ton TNT test on 1000 ft section of London Underground tube at Suffield, Alberta, 3 Aug 1961




Atomic Weapons Research Establishment, "1/40th Scale Experiment to Assess the Effect of Nuclear Blast on the London Underground System", Report AWRE-E2/62, 1962, Figure 30. (National Archives ES 3/57.)

These trials are described in a preliminary report[5] prepared for the Advisory Group by A.W.R.E. It was shown that the blast pressure inside a tunnel system, having openings at intervals to ground level, is less than the pressure at ground level at any distance from the explosion, by a factor of about 3. This reduction in pressure was apparently caused by the station entrances acting as expansion chambers. This observation was of outstanding significance to the consideration of London tubes as shelter.

All previous research on blast in tunnels - and a great amount of work was done on this in the last war - had been conducted with blast entering the open end of a tunnel without side openings. This research had shown that the blast, once it had got into a tunnel, tended to travel great distances without appreciable diminution. This had, therefore, led to the general belief that the London tubes could be death traps rather than shelters.

The more recent research here described showed for the first time that a person sheltering in a tube would be exposed to a blast pressure only about $\frac{1}{3}$ as great as he would be exposed to if he was above ground. (In addition, of course, he would be fully protected from fallout in the tube.)

In fact A.W.R.E. carried out two further tests, with more accurate scaling of station volumes based on more detailed information from the London Transport Executive. A full report on all four tests is in preparation.

These later tests showed that the pressure in station tunnels was only about 1/6th of the ground-level pressure, but that the reduction was not so great in the smaller-diameter train tunnels.

At this stage the Advisory Group were reasonably satisfied that this problem - of blast entry from stations - had been solved. But the other major question of blast entry direct from the crater remained in doubt, on account of the very small scale of the tests to date. Therefore, when the opportunity arose of testing at a really large scale at Suffield, Canada, it was naturally accepted.

## Large-Scale Field Test (1/40) at Suffield, Alberta

The test is fully described in an A.W.R.E. report[6]. The decision of the Canadian Defence Research Board to explode very large amounts of high explosive provided a medium for a variety of target-response trials that was welcome at a time when nuclear tests in Australia were suspended. A.W.R.E. used the 100-ton explosion in 1961 to test, among other items, the model length of the London tube, at 1/40th scale, that had already been tested at 1/117 scale.

## Blast Entry from Stations

There was remarkable agreement with the 1/117th scale trials: "maximum overpressure in the train tunnels was of the order of $\frac{1}{3}$rd the corresponding peak shock overpressure in the incident blast. The pressures in the stations were about 1/6th those in the corresponding incident blast ....... ". In comparing the results at the two scales it was noted that the pressures in the train tunnels (between stations) was higher at Suffield than at the smaller scale; this may, the report suggests, have been due to some blast entry from the crater at Suffield.

## Blast Entry from the Crater

There may - as has just been noted - have been some entry of blast at the crater. But the all-important fact is that it was nowhere enough to bring the pressure in the tunnel up to more than a $\frac{1}{3}$rd of the free-air pressure (see fig. 30 reproduced, and attached to this note.) From this, and from a detailed study of tunnel rings ejected by the explosion over a wide area, it can be concluded that the instantaneous crushing of the tube near the crater sealed it against the entry of any significant blast pressure.

## Air Flow in Stations

The Report indicates that there would be turbulence generated by blast entry at stations and that there would be a danger to occupants there, on account of blast "windage" acting on them and on missiles that could injure them. This danger would be less in the train tunnels between stations.

## Conclusion

The Advisory Group discussed the Suffield Test on tunnels on Nov. 1st 1962, and concluded that model experiments have successfully demonstrated that the risks from blast inside the London tubes would be less than above ground. The Group considered that the results obtained were consistent enough to provide as good an estimate of full-scale effects from megaton weapons as was likely to be obtainable, and that the Chairman could advise the Home Office confidently on the basis of these results. The Group accepted that there would be a risk of casualty-producing air flow in stations, but decided to defer a decision on whether further research on this problem would be profitable. The Chairman said that he would first convey the results of the completed research to the Shelter Division of the Home Office before asking the Group whether it was worth studying this remaining, but less important, problem.

3rd October, 1963.

## References


(1) Advisory Group on Structural Research for Civil Defence

Note by Chairman on the Structural Research Programme for Shelters. SAB/SG(57)6. (Restricted)

(2) Notes of Meeting on 15th May 1957. SAB/SG(57)2nd Minutes (Confidential)

(3) The Entry of Air Blast from Craters into Tunnels. A.W.R.E. Report E1/59 (Official Use Only)

(4) The Effect of Tunnel Blockage on Shock Waves .... SAB/SG(58)6 (Confidential)

(5) Model Experiments on the Entry of Blast into the London Underground System, Interim Report on Rounds 1 and 2. SAB/SG(59)4 (Confidential)

(6) 1/40th Scale Experiment to Assess the Effect of Nuclear Blast on the London Underground System. A.W.R.E. Report E2/62. (Official Use Only.)

Proceedings of the Symposium
held at Washington, D. C.
April 19-23, 1965 by the
Subcommittee on Protective Structures,
Advisory Committee on Civil Defense,
National Academy of Sciences—
National Research Council

# Protective Structures for CIVILIAN POPULATIONS

1966

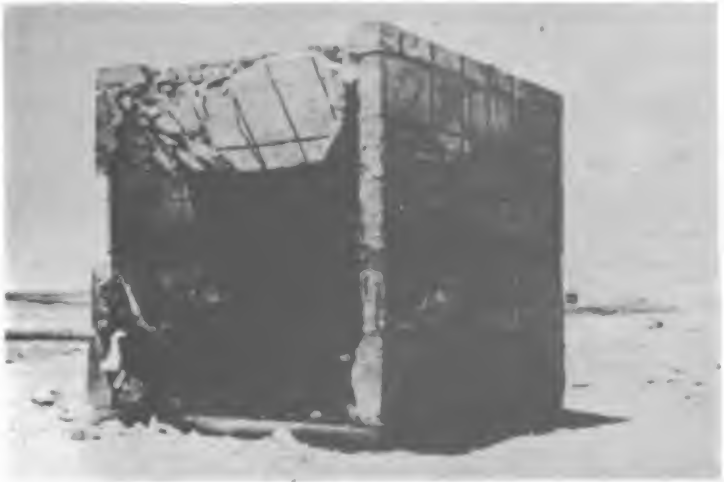
# MODEL ANALYSIS


Mr. Ivor Ll. DAVIES
Suffield Experimental Station
Canadian Defense Research Board
Ralston, Alberta, Canada


## Nuclear-Weapon Tests

In 1952 we fired our first nuclear device, effectively a "nominal" weapon, at Monte Bello, off northwest Australia. To the blast loading from this weapon we exposed a number of reinforced-concrete cubicle structures that had been designed for the dynamic loading conditions, and for which we made the best analysis of response we were competent to make at that time. Our estimates of effects were really a dismal failure. The structures were placed at pressure levels of 30, 10, and 6 psi, where we expected them to be destroyed, heavily damaged with some petaling of the front face, and extensively cracked, respectively. In fact, the front face of the cubicle at 30 psi was broken inwards; failure had occurred along both diagonals, and the four triangular petals had been pushed in. At the 10-psi level, where we had three cubicles, each with a different wall thickness (6, 9, and 12 in.), we observed only light cracking in the front face of that cubicle with the least thick wall (6 in.). The other two structures were apparently undamaged, as was the single structure at the 6-psi level.

10 p.s.i.



34 p.s.i.

Dynamic tests, Monte Bello cubicles.

In 1957, the first proposals were made for the construction of the underground car park in Hyde Park in London. The Home Office was interested in this project since, in an emergency, the structure could be used as a shelter. Consequently a request was made to us at Atomic Weapons Research Establishment (A.W.R.E.) to design a structure that would be resistant to a blast loading of about 50 psi, and to test our design on the model scale.

Using the various load-deformation curves obtained in this test, an estimate was made of the response of the structure to blast loading. Of particular interest was the possible effect of 100 tons of TNT, the first 100-ton trial at Suffield in Alberta.

A total of seven more models was made; six were shipped to Canada and placed with the top surface of the roof flush with the ground and at positions where peak pressures of 100, 80, 70, 60, 50, and 40 psi were expected. The seventh model was kept in England for static testing at about the time of firing. The results were not as expected. In the field, the four models farthest from the charge were apparently undamaged; we could see no cracking with the eye, nor did soaking the models with water reveal more than a few hair cracks. The model nearest the charge was lightly cracked in the roof panels and beams, and one of the columns showed slight spalling at the head. This model had been exposed to a peak pressure of 110 psi.

# BLAST AND OTHER THREATS

Harold Brode
The RAND Corporation, Santa Monica, California

## Chemical High-Explosive Weapons

As in past aerial warfare, bombs and missiles carrying chemical explosives to targets are capable of extensive damage only when delivered in large numbers and with high accuracy.

## Biological Warfare

Most biological agents are inexpensive to produce; their effective dissemination over hostile territories remains the chief deterrent to their effective employment. Twenty square miles is about the area that can be effectively covered by a single aircraft; large area coverage presents a task for vast fleets of fairly vulnerable planes flying tight patterns at modest or low altitudes. While agents vary in virulence and in their biologic decay rate, most are quite perishable in normal open-air environments. Since shelter and simple prophylactic measures can be quite effective against biological agents, there is less likelihood of the use of biological warfare on a wholesale basis against a nation, and more chance of limited employment on population concentrations —perhaps by covert delivery, since shelters with adequate filtering could insure rather complete protection to those inside.

## Chemical Weapons

Chemical weapons, like biological weapons, are relatively inexpensive to create, but face nearly insurmountable logistics problems on delivery. Although chemical agents produce casualties more rapidly, the greater amounts of material to deliver seriously limit the likelihood of their large-scale deployment. Furthermore, chemical research does not hold promise of the development of significantly more toxic chemicals for future use.

## Radiological Weapons

The advantages of such modifications are much less real than apparent. In all weapons delivered by missiles, minimizing the payload and total weight is very important. If the total payload is not to be increased, then the inclusion of inert material to be activated by neutrons must lead to reductions in the explosive yield. If all the weight is devoted to nuclear explosives, then more fission-fragment activity can be created, and it is the net difference in activity that must be balanced against the loss of explosive yield. As it turns out, a fission explosion is a most efficient generator of activity, and greater total doses are not achieved by injecting special inert materials to be activated.

Perret, W.R., Ground Motion Studies at High Incident Overpressure, The Sandia Corporation, Operation PLUMBBOB, WT-1405, for Defense Atomic Support Agency Field Command, June 1960.

## The Neutron Bomb

The neutron bomb, so called because of the deliberate effort to maximize the effectiveness of the neutrons, would necessarily be limited to rather small yields—yields at which the neutron absorption in air does not reduce the doses to a point at which blast and thermal effects are dominant. The use of small yields against large-area targets again runs into the delivery problems faced by chemical agents and explosives, and larger yields in fewer packages pose a less stringent problem for delivery systems in most applications. In the unlikely event that an enemy desired to minimize blast and thermal damage and to create little local fallout but still kill the populace, it would be necessary to use large numbers of carefully placed neutron-producing weapons burst high enough to avoid blast damage on the ground, but low enough to get the neutrons down. In this case, however, adequate radiation shielding for the people would leave the city unscathed and demonstrate the attack to be futile.

The thermal radiation from a surface burst is expected to be less than half of that from an air burst, both because the radiating fireball surface is truncated and because the hot interior is partially quenched by the megatons of injected crater material.

### SUPERSEISMIC GROUND-SHOCK MAXIMA (AT 5-FT DEPTH)

Vertical acceleration: $\alpha_{vm} \simeq 340\,\Delta P_s/C_L$ ± 30 per cent. Here acceleration is measured in g's and overpressure ($\Delta P_s$) in pounds per square inch. An empirical refinement requires $C_L$ to be defined as the seismic velocity (in feet per second) for rock, but as three fourths of the seismic velocity for soil.

### OUTRUNNING GROUND-SHOCK MAXIMA (AT ~10-FT DEPTH)

Vertical acceleration: $\alpha_{vm} \simeq 2 \times 10^5/C_L r^2$ + factor 4 or -factor 2. Acceleration is measured in g's, and r is the scaled radial distance—i.e., $r = R/W^{1/3}$ kft/(mt)$^{1/3}$.

Data taken on a low air-burst shot in Nevada indicate an exponential decay of maximum displacement with depth. For the particular case of a burst of ~ 40 kt at 700 ft, some measurements were made as deep as 200 ft below the surface of Frenchman Flat, a dry lake bed, which led to the following approximate decay law, according to Perret.

$$\delta = \delta_0 \exp(-0.017D),$$

where $\delta$ represents the maximum vertical displacement induced at depth D, $\delta_0$ is the maximum displacement at the surface, and D is the depth in feet.

# THE PROTECTION AGAINST FALLOUT RADIATION AFFORDED BY CORE SHELTERS IN A TYPICAL BRITISH HOUSE

**Daniel T. Jones**
**Scientific Adviser, Home Office, London**

Protective Factors in a Sample of British Houses (Windows Blocked)

| Protective Factor | Percentage of Houses |
|---|---|
| < 25 | 36% |
| 25-39 | 28% |
| 40-100 | 29% |
| > 100 | 7% |

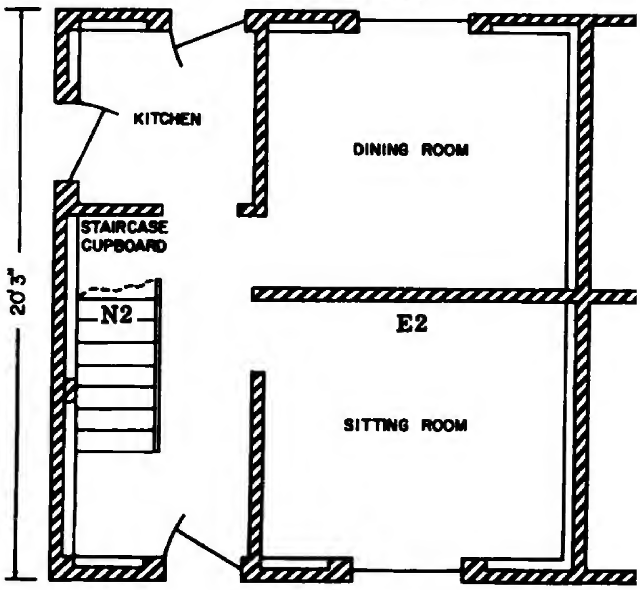
"A very much improved protection could be obtained by constructing a shelter core. This means a small, thick-walled shelter built preferably inside the fallout room itself, in which to spend the first critical hours when the radiation from fallout would be most dangerous."(1)

The full-scale experiments were carried out at the Civil Defense School at Falfield Park.(2)

In the staircase construction, the shelter consisted of the cupboard under the stairs, sandbags being placed on treads above and at the sides.

A 93 curies cobalt-60 source was used.

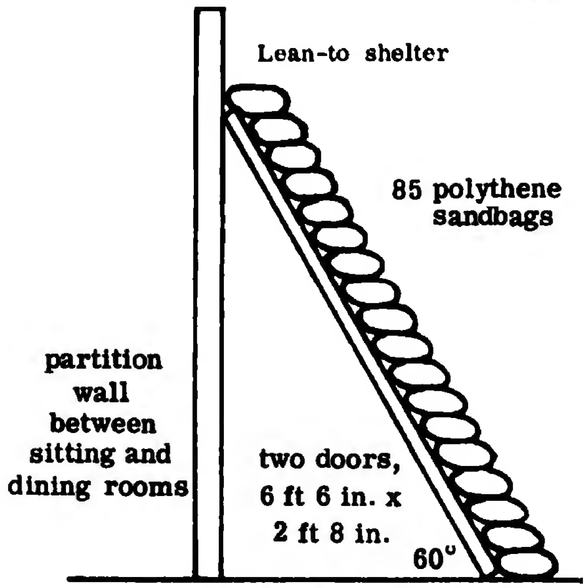
1. Six sandbags per tread, and a double layer on the small top landing. 96 sandbags were used.
2. As (1), together with a 4-ft-high wall of sandbags along the external north wall. 160 sandbags were used.
3. As (2), together with 4-ft-high walls of sandbags along the kitchen/cupboard partition wall and along the passage partition. 220 sandbags were used.




sandbags 24 in. x 12 in. when empty; 16 in. x 9 in. x 4 in. when filled with 25 lb of sand.

| 9 in. brick walls<br>The windows and doors were not blocked | Position | contribution r/hr/c/ft$^2$ Ground | Roof | Protective Factor |
|---|---|---|---|---|
| House only | E2 | 15.0 | 8.4 | 21 |
| Lean-to | E2 | 10.4 | 2.4 | 39 |
| Staircase cupboard: | | | | |
| Stairs only sandbagged | N2 | 29.2 | 5.3 | 14 |
| Stairs and outer wall sandbagged | N2 | 16.4 | 4.6 | 24 |
| Stairs, outer wall, kitchen wall and corridor partition sandbagged | N2 | 8.8 | 1.8 | 47 |

1. Civil Defence Handbook No. 10, HMSO, 1963.
2. Perryman, A. D., Home Office Report CD/SA 117.




floor area 21 sq ft.

## Foreword

If the country were ever faced with an immediate threat of nuclear war, a copy of this booklet would be distributed to every household as part of a public information campaign which would include announcements on television and radio and in the press. The booklet has been designed for free and general distribution in that event. It is being placed on sale now for those who wish to know what they would be advised to do at such a time.

*May 1980*

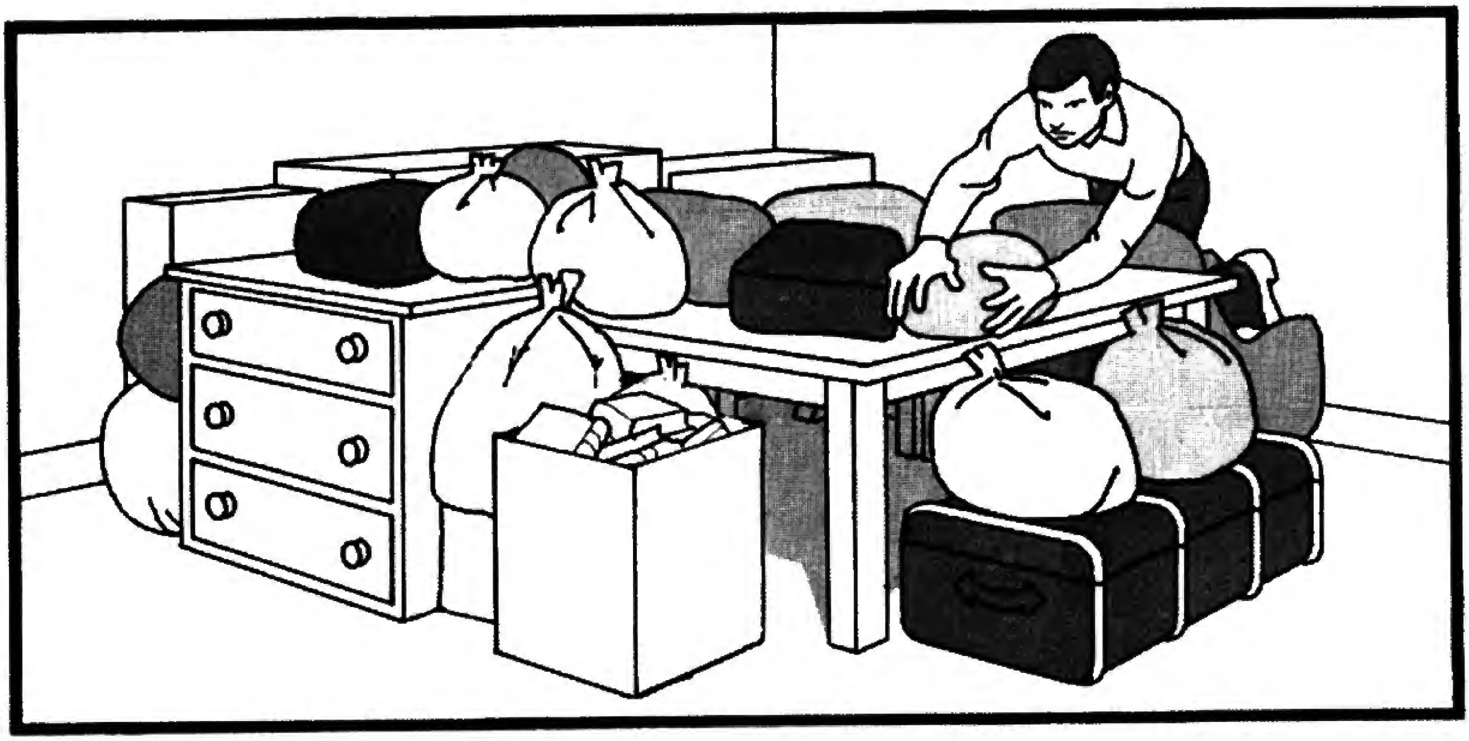
*Protect and Survive*
ISBN 0 11 3407289

If Britain is attacked by nuclear bombs or by missiles, we do not know what targets will be chosen or how severe the assault will be.

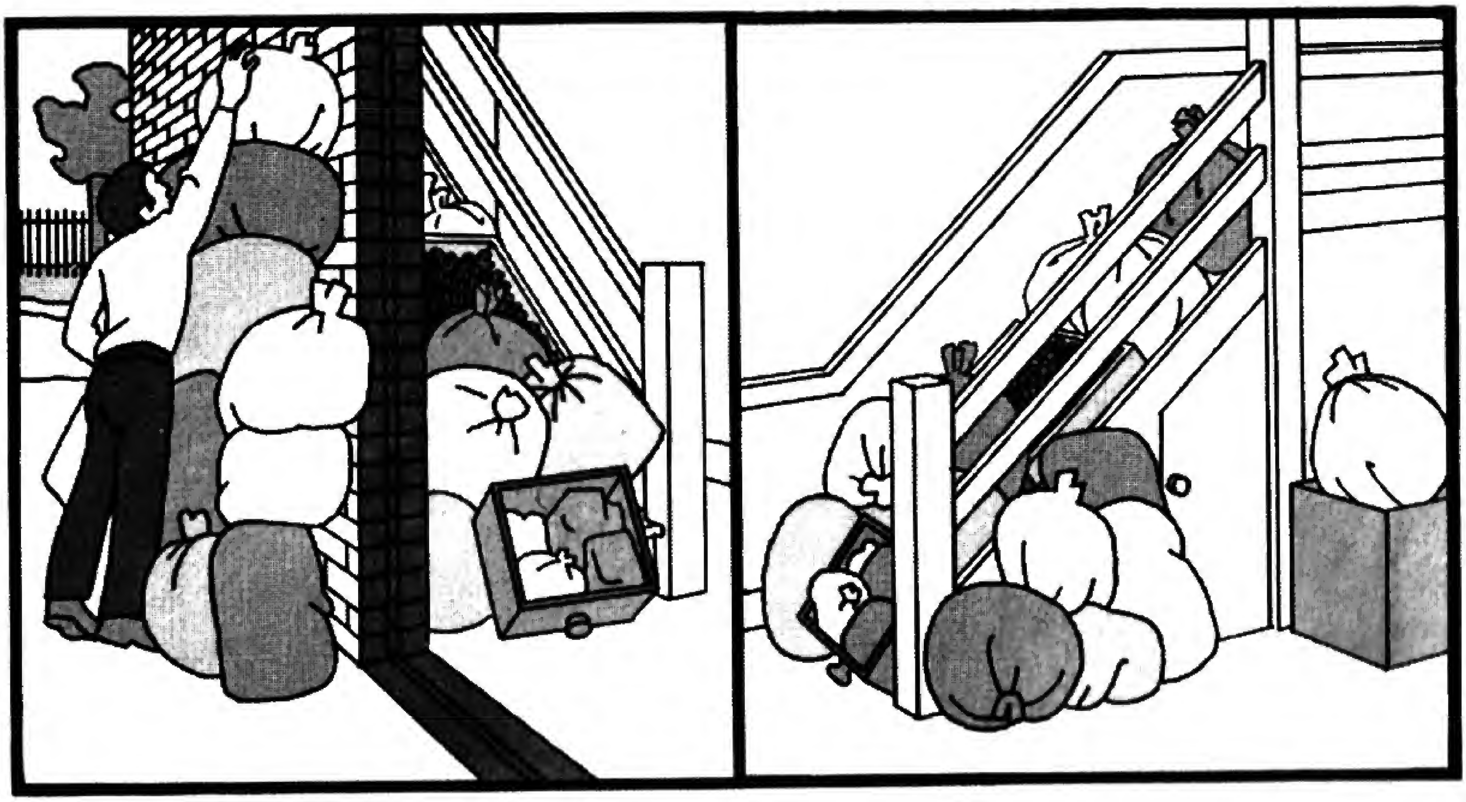
If nuclear weapons are used on a large scale, those of us living in the country areas might be exposed to as great a risk as those in the towns. The radioactive dust, falling where the wind blows it, will bring the most widespread dangers of all. No part of the United Kingdom can be considered safe from both the direct effects of the weapons and the resultant fall-out.

The dangers which you and your family will face in this situation can be reduced if you do as this booklet describes.

Use tables if they are large enough to provide you all with shelter. Surround them and cover them with heavy furniture filled with sand, earth, books or clothing.



Use the cupboard under the stairs if it is in your fall-out room. Put bags of earth or sand on the stairs and along the wall of the cupboard. If the stairs are on an outside wall, strengthen the wall outside in the same way to a height of six feet.



# What to do after the Attack:

After a nuclear attack, there will be a short period before fall-out starts to descend. Use this time to do essential tasks. This is what you should do.

Do not smoke.

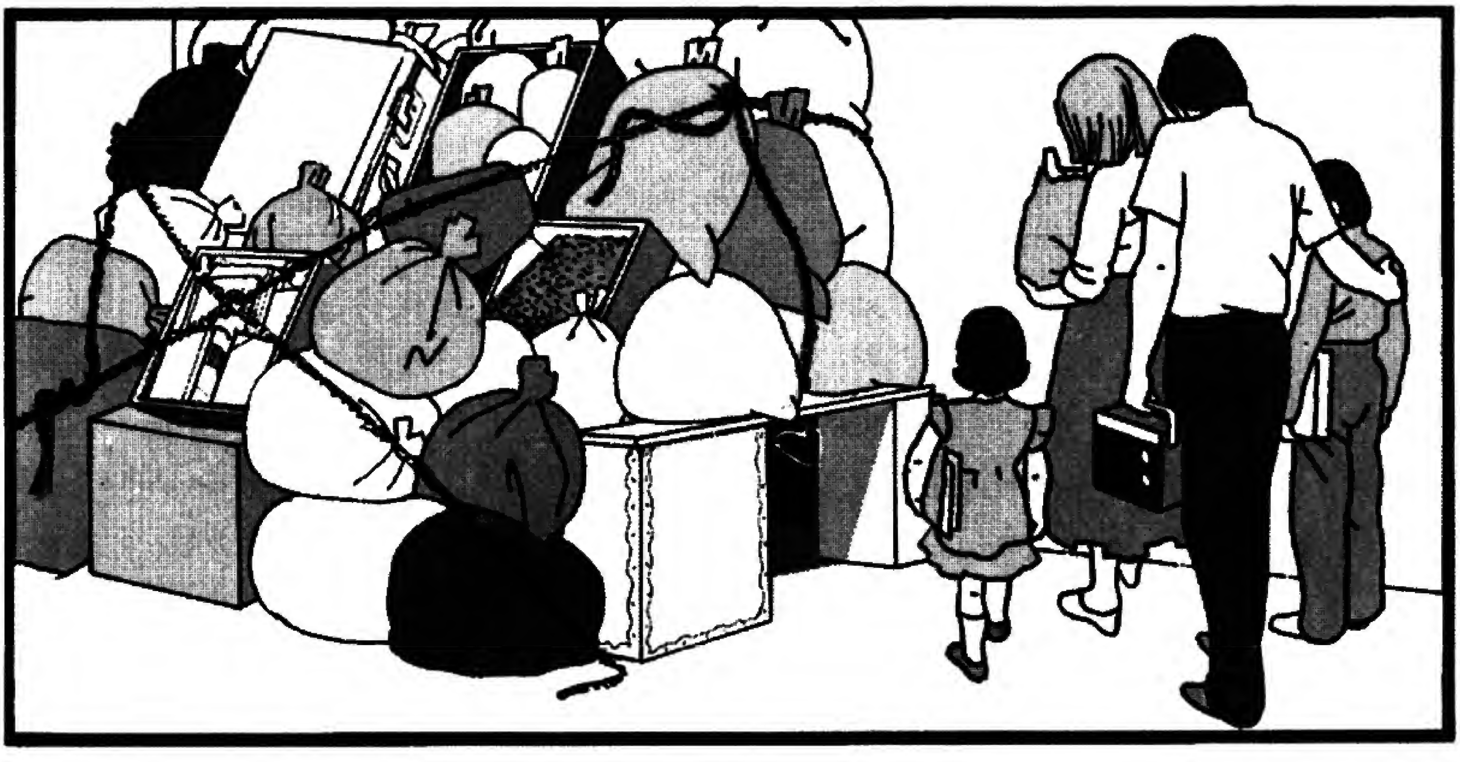
Check that gas, electricity and other fuel supplies and all pilot lights *are* turned off.

Go round the house and put out any small fires using mains water if you can.

If anyone's clothing catches fire, lay them on the floor and roll them in a blanket, rug or thick coat.

If there is structural damage from the attack you may have some time before a fall-out warning to do minor jobs to keep out the weather – using curtains or sheets to cover broken windows or holes.

If you are out of doors, take the nearest and best available cover as quickly as possible, wiping all the dust you can from your skin and clothing at the entrance to the building in which you shelter.



HOME OFFICE
SCOTTISH HOME DEPARTMENT

MANUAL OF CIVIL DEFENCE

Volume I

PAMPHLET No. 1

# NUCLEAR WEAPONS

*LONDON*
HER MAJESTY'S STATIONERY OFFICE
1956

30 Research into the causes of fire in Hiroshima and Nagasaki, combined with a study of the secondary fire risk from the flying bomb damage in this country during the last war has shown that with nuclear attack the secondary fire risk is likely to be small compared with the primary risk of direct ignition by thermal radiation.

**Fire precautions**

31 Although the fire risk even from a nominal bomb is always serious, targets in this country, where the great majority of buildings are of brick, stone or concrete, are less vulnerable to fire than were those in Japan, where most of the buildings were of wood.

32 since the thermal radiation has no great penetrating power, any opaque screen, especially a white one, will keep it out:

33 Another obvious fire precaution is the removal of all readily combustible material from the direct path of any heat radiation that could possibly enter windows or other openings.

34 Both these precautions apply only to those windows and other openings that have a direct view of some part of the sky.

**The probable fire situation in a British city**

35 Japanese houses are constructed of wood and once they were set on fire they continued to burn even when knocked over. In this country only about 10 per cent. of all the material in the average house is combustible, and under conditions of complete collapse, where air would be almost entirely excluded, it is doubtful whether a fire could continue on any vigorous scale.

38 The Hiroshima bomb (but not the Nagasaki one) caused a fire storm. A fire storm occurred in Hamburg and possibly also in several other German cities as a result of accurate and very dense attacks with incendiary and high explosive bombs by the R.A.F. Information on the subject is limited, but it has been fairly well established that during these particular raids on Germany half the buildings in the target area were set on fire in about half an hour. In such circumstances it seems that nothing can prevent all the fires from joining together into one mass fire engulfing the whole area.

40 It seems unlikely from the evidence available that an initial density of fires equivalent to one in every other building would be started by a nuclear explosion over a British city. Studies have shown that a much smaller proportion of buildings than this would be exposed to thermal radiation and even then it is not certain that continuing fires would develop. Curtains may catch fire, but it does not necessarily follow that they will set light to the room; in the last war it was found that only one incendiary bomb out of every six that hit buildings started a continuing fire.

From a 10 megaton bomb, with its longer lasting thermal radiation (see paragraph 21), it takes about 20 calories per square centimetre to start fires because so much of the heat (spread out over the longer emission) is wasted by conduction into the interior of the combustible material and by convection and re-radiation whilst the

temperature of the surface is being raised to the ignition point. But the distance at which 20 calories per square centimetre can be produced is only 11 miles, so that the scaling factor for a 10 megaton airburst bomb is therefore 11 and not 22.

43 For a ground burst bomb, however, several other factors contribute to a further reduction in the fire range. Apart from an actual loss of heat by absorption into the ground and from the pronounced shielding effect of buildings, the debris from the crater tends to reduce the radiating temperature of the fireball and a greater proportion of the energy is consequently radiated in the infra red region of the spectrum —this proportion being more easily absorbed by the atmosphere.

44 An important point in relation to personal protection against the effects of hydrogen bomb explosions is that because the thermal radiation lasts so long there is more time for people who may be caught in the open, and who may be well beyond the range of serious danger from blast, to rush to cover and so escape some part of the exposure. For example, people in the open might receive second degree burns (blistering) on exposed skin at a range of 16 miles from a 10 megaton ground burst bomb (8×2—see paragraph 24). If, however, they could take cover in a few seconds they would escape this damage. Moreover, at this range the blast wave would not arrive for another minute and a half so that any effects due to the blast in the open (e.g. flying glass, etc.) could be completely avoided.

# DOMESTIC NUCLEAR SHELTERS

# TECHNICAL GUIDANCE

A HOME OFFICE GUIDE

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# Introduction

This manual of technical guidance on the design of domestic nuclear shelters has been prepared by a working group set up by the Emergency Services Division of the Home Office. The working group was asked to consider designs of nuclear shelters which could be made available to members of the public in the United Kingdom who might wish to purchase and install shelters for the use of themselves and their families.

The working group realised that the range of designs which it might produce would not be exhaustive. However, it was aware of the need to give technical guidance to professional engineers to assist them in producing reliable shelter designs. Thus the first three chapters of this book are written to give such guidance.

The other four chapters of the book give detailed designs of five shelters. These five cover a range of types which are applicable to different sorts of houses; they also cover a wide price range. These designs are not intended to be exhaustive, and as explained in the text, the working group is already giving attention to other designs, particularly those which might be incorporated into existing or new houses and also underground shelters of shapes other than box-like and using materials other than concrete. It is planned to publish details of this work at a later date.

The members of the working group are:

| | |
|---|---|
| Mr J C Cotterill, *Chairman* | Scientific Advisory Branch, Home Office |
| Dr J R Stealey | Scientific Advisory Branch, Home Office |
| Mr A Lindfield | Scientific Advisory Branch, Home Office |
| Mr K A Day | F6 Division, Home Office |
| Mr R W T Haines, C Eng | Directorate of Works, Home Office |
| Mr H G S Banks, C Eng | Directorate of Works, Home Office |
| Mr M Connell, C Eng | Directorate of Civil Engineering Services Property Services Agency, Department of Environment |
| Mr S Bell, C Eng | Directorate of Civil Engineering Services Property Services Agency, Department of Environment |
| Mr S England, C Eng | Directorate of Mechanical and Electrical Engineering Services Property Services Agency, Department of Environment |
| Mr I Leys | Atomic Weapons Research Establishment, Ministry of Defence Foulness |
| Major I C T Ingall | HQ United Kingdom Land Forces Wilton, Wilts. |
| Mr R Million, *Secretary* | F6 Division, Home Office |

Any enquiries concerning this manual should be addressed to the Home Office, F6 Division, and not to individual members of the working group.

To obtain some protection from the heat it is necessary to move out of the direct path of the rays from the fireball; any kind of shade will be of some value.

A fire-storm occurred only in an area of several square miles, heavily built up with buildings containing plenty of combustible material and where at least every other building in the area had been set alight. It is not considered that the initial density of fires, equivalent to one in every other building, would be caused by a nuclear explosion over a British city. Studies have shown that due to shielding, a much smaller proportion of buildings than this would be exposed to the heat flash. Moreover, the buildings in the centres of most British cities are now more fire-resistant and more widely spaced than they were 30 to 40 years ago. This low risk of fire-storms would be reduced still further by the control of small initial and secondary fires.

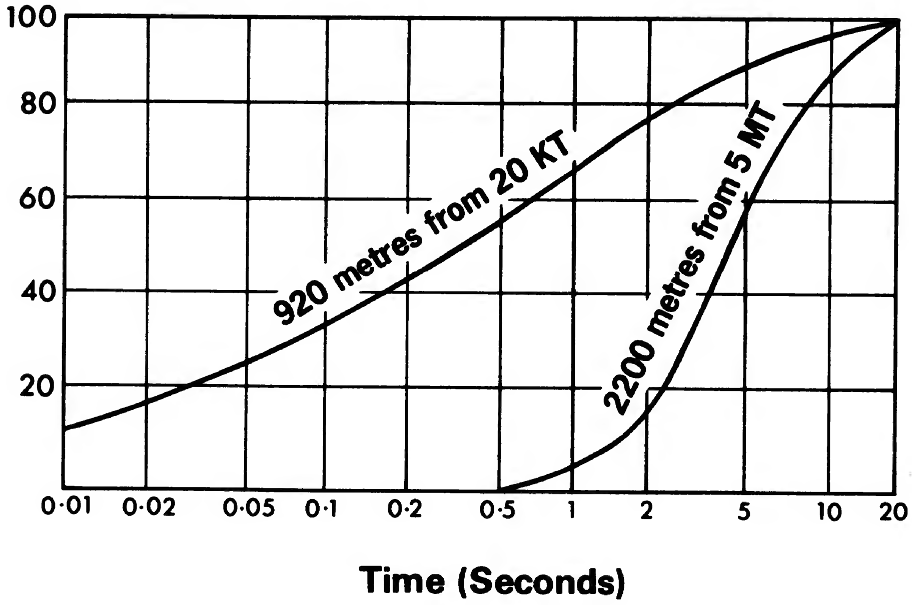
**Fig. 8** ***Half-value thicknesses of shielding materials***

| | Against INR mm | (inches) | Against fallout radiation mm | (inches) |
|---|---|---|---|---|
| Steel | 38 | (1.5) | 18 | (0.7) |
| Concrete | 152 | (6.0) | 56 | (2.2) |
| Earth | 190 | (7.5) | 84 | (3.3) |
| Water | 330 | (13.0) | 122 | (4.8) |
| Brickwork | 157 | (6.2) | 71 | (2.8) |

The amount of scattering of initial gamma radiation depends upon a number of factors, but probably amounts to about 10 per cent of that in the main beam.

Fig. 9 gives the percentage of initial gamma radiation dose received as a function of time for 20 KT and 5 MT air bursts. It can be seen that in the former case about 65 per cent and in the latter case 5 per cent of the total initial gamma radiation dose is received during the first second. In the case of the higher yield weapon it can be seen that if some shelter could be obtained within one second of seeing the explosion flash, such as by falling prone behind some substantial object, it could make the difference between life and death. Such an action would also help to prevent the translational effect of the blast.

Fig. 9 *Percentage of total initial gamma dose received*



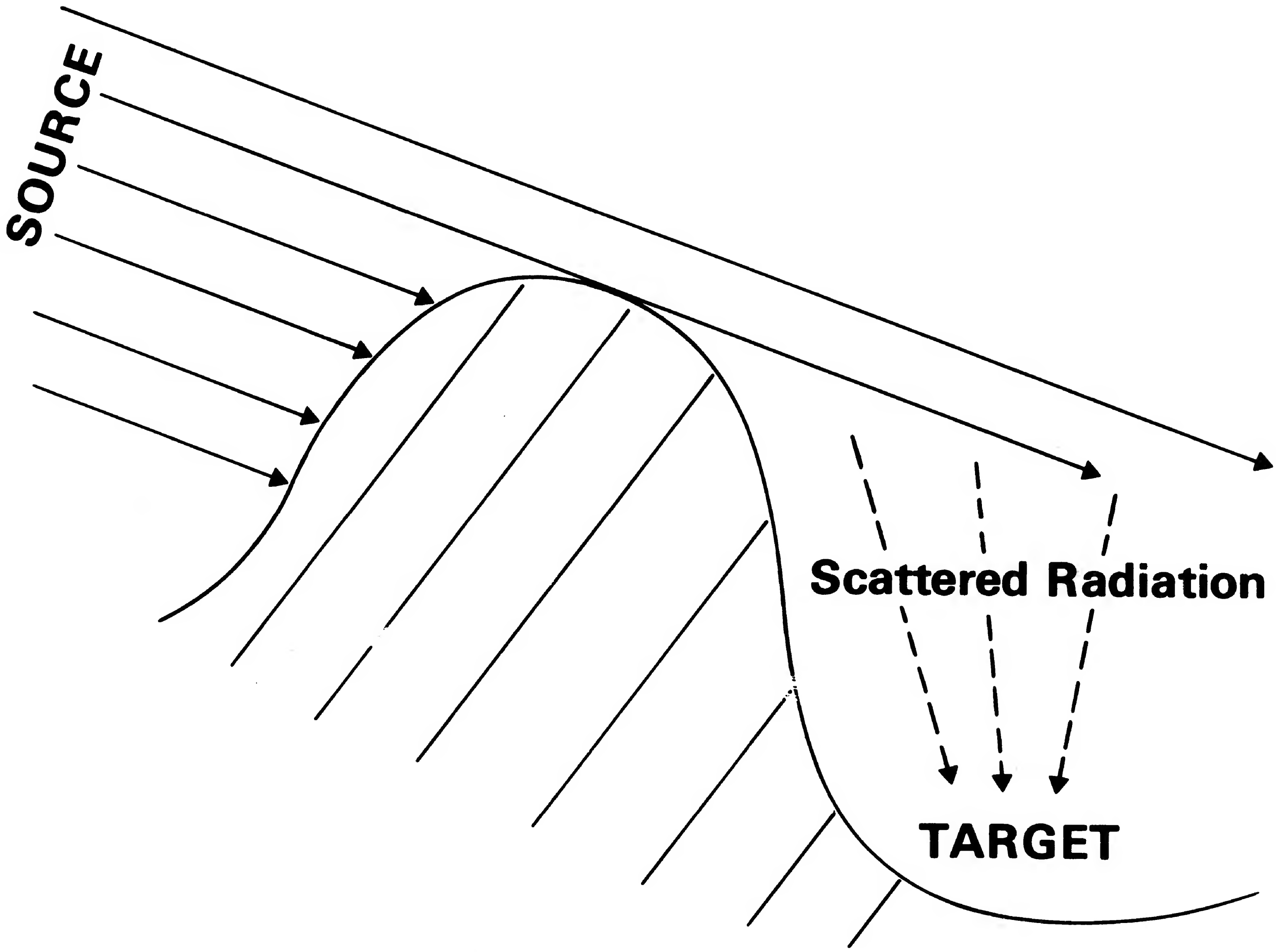




Fig. 10 *Target exposed to scattered gamma radiation from a nuclear burst*

## *Further comments on protection against INR and fallout radiation*

Fig. 12 gives a comparison of the protective factors against INR gamma, neutrons and fallout radiation of some typical buildings. The data has been taken from *Effects of Nuclear Weapons* and the choice has been made of those buildings which are reasonably comparable with structures in the UK. The wide range of values is due partly to uncertainty in the data (since some have been calculated and others derived from weapons trials) and partly to the fact that protection to some extent is determined by the position in the building where the protective factor is measured.

**Fig. 12** ***Protective factors of various buildings against initial gamma, neutron and fallout gamma radiation***

| Structure | Initial gamma | Neutrons | Fallout gamma |
|---|---|---|---|
| 1 metre underground | 250–500 | 100–500 | 5000 |
| Shelter partly above ground:<br>with 600 mm earth<br>900 mm earth | <br><br>15–35<br>50–150 | <br><br>12–50<br>20–100 | <br><br>50–200<br>200–1000 |

## Summary of effects of nuclear weapons

From this brief review of the effects of nuclear weapons we can list the order of events from the detonation of a weapon. These are:

(a) Light and heat flash – immediate, and lasting some seconds.

(c) Blast wave – following from about a half second to several seconds after the light and heat flash.

(d) Fires – these may have been ignited by the heat flash

(e) Fallout – about one half hour to several hours after burst.

## Considerations arising from the probable attack pattern

In section 1.1.1 reference was made to the fact that an expected attack pattern on the United Kingdom might use 200 megatons on about 80 targets. If we now make an assumption that this attack would be in the form of 100 weapons of 1 MT airbursts and 100 weapons of 1 MT groundbursts we can use the information given in Fig. 6 to indicate the probability of areas being subject to various effects.

On this assumption, we should find that about 2.2 per cent of the land area of the UK would be subject to overpressures in the 'A' ring of 77 kPa (11 psi) and above about 1.8 per cent would be subject to overpressures of between 42 and 77 kPa (6-11 psi) in the 'B' ring and about 10 per cent of the land area would be subject to overpressures of between 10 and 42 kPa (1.5 to 6 psi). The rest of the land area, about 85 per cent, would be subject to blast in the D ring of 5 to 10 kPa (0.75 to 1.5 psi) or to no blast at all. Blast effects in the D ring will cause minor damage to buildings and no lethalities.

SEPTEMBER 1964

# HOME OFFICE

CD/SA 121

# SCIENTIFIC ADVISER'S BRANCH

## IGNITION AND FIRE SPREAD IN URBAN AREAS FOLLOWING A NUCLEAR ATTACK

G. R. Stanbury

### INITIAL FIRE INCIDENCE

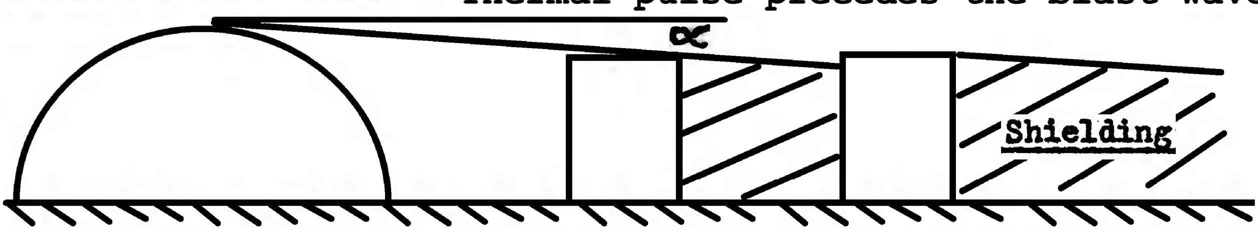
For a 1 MT groundburst bomb the height of the top of the fireball above ground is about 0.72 miles. Because this distance is large compared with the height of most buildings, the exposed upper floors do actually see a large part of the fireball and not just the top of it, but in assuming that the radiation is just as intense from the top as from the middle we were overestimating the fire risk.

On the above basis the following table gives the number of exposed upper floors (to the nearest ½ floor) for a range of distances from the explosion and a range of street widths.

### Effect of Shielding: Estimation of the number of exposed floors

Assuming that buildings on opposite sides of a street which is receiving heat radiation from a direction perpendicular to its length are of the same height

Thermal pulse precedes the blast wave




| Distance from explosion miles | Angle of arrival $\alpha^{o}$ | tan $\alpha$ | Width of street (units of 10 ft.) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 35 | .72 | 1.5 | 2 | 3 | 3.5 | 4.5 | 5 | 6 |
| 1½ | 26 | .48 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 |
| 2 | 20 | .36 | .5 | 1 | 1.5 | 2 | 2 | 2.5 | 3 |
| 3 | 13½ | .24 | .5 | .5 | 1 | 1 | 1.5 | 1.5 | 2 |
| 4 | 10 | .18 | .5 | .5 | .5 | 1 | 1 | 1.5 | 1.5 |
| 5 | 8 | .15 | .5 | .5 | .5 | .5 | 1 | 1 | 1 |

we take the average depth of a floor to be 10 ft.

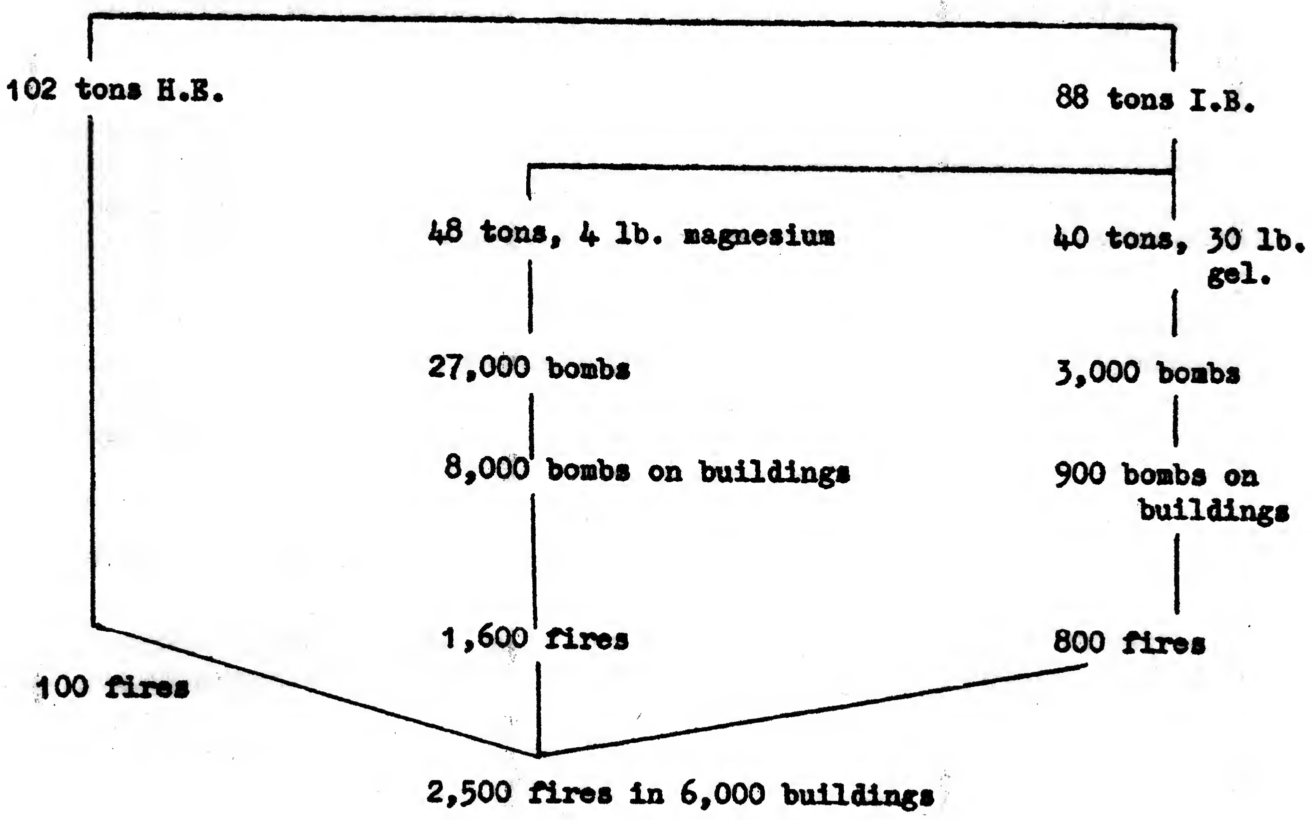
| | | | | | | |
|---|---|---|---|---|---|---|
| Angle between heat flash and street (degrees) | 90-75 | 75-60 | 60-45 | 45-30 | 30-15 | 15-0 |
| Proportion of heat flash entering windows % | 99 | 92.5 | 80 | 60 | 40 | 14 |

## SPREAD OF FIRE

From last war experience of mass fire raids in Germany it was concluded that the overall spread factor was about 2; i.e. about twice as many buildings were destroyed by fire as were actually set alight by incendiary bombs

**Number of fires started per square mile in the fire-storm raid on Hamburg, 27th/28th July, 1943**

**Bombs dropped**




However, the important thing to note is that the total number of fires started in each square mile (2,500) was nearly half that of the total number of buildings; in other words, almost every other building was set on fire during the raid itself. When this happened no fire-fighting organisation, however efficient could hope to prevent the fires from joining together and engulfing the whole area.

When the figure of 1 in 2 for the German fire storms is compared with the figures for initial fire incidence of $\sim$ 1 in 15 to 30 obtained in the Birmingham and Liverpool studies it can only be concluded that a nuclear explosion could not possibly produce a fire storm.

## Fire situation from 1,499 fly bombs in the built-up part of the London Region

WWII VI high explosives (1 ton TNT warhead) (cruise missiles)

| Where dropped | Number of fly bombs | Fly Bombs Caused | | | | |
|---|---|---|---|---|---|---|
| | | No fire | Small fire | Medium fire | Serious fire | Major fire |
| City | 119 ~~199~~ | 47 | 49 | 17 | 4 | 2 |
| West-End | 33 | 8 | 22 | 2 | - | 1 |
| Closed Residential | 430 | 207 | 203 | 20 | - | - |
| Open Residential | 804 | 478 | 296 | 28 | 2 | - |
| Docks | 113 | 64 | 39 | 8 | 1 | 1 |
| Grand Totals | 1,499 | 804 | 609 | 75 | 7 | 4 |

### Discussion of results

Two important points emerge from a study of these results:-

(i) The small proportion of fly bombs - less than 20% - which started fires of any greater category than "small" even in the most heavily built-up areas; and

(ii) The large proportion which started no fires at all even in the most heavily built-up areas.

All these fly bombs fell in the summer months of 1944 which were unusually dry. In winter in this country in residential areas there are many open fires which may provide extra sources of ignition. The domestic occupancy is a low fire risk however, and as the proportion of such property in the important City and West End areas is small this should not introduce any serious error. Moreover, in winter, the high atmospheric humidity and the correspondingly high moisture content of timber would tend to retard or even prevent the growth of fire.

In order to determine how many fly bombs are equivalent to one nominal atomic bomb one method is to compare the areas over which a given category of house damage is produced by each. If we do this for a $\frac{3}{8}$th mile air burst as at Hiroshima, the result is that 1 atomic bomb does as much damage as about 1,200 fly bombs.

This in itself is not a serious fire situation and it is doubtful whether it could ever give rise to a fire storm. In Hamburg 2,500 fires were started per square mile by a bomb density (combined H.E. and I.B.) of 2oo tons per square mile, and for the area of destruction produced by an atomic bomb this would correspond to a total of about 10,000 fires.

UCRL-TR-231593

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# Thermal Radiation from Nuclear Detonations in Urban Environments

R. E. Marrs, W. C. Moss, B. Whitlock

June 7, 2007

An obvious next step (left for future work) would be a calculation of burn injuries and fires. Even without shadowing, the location of most of the urban population within buildings causes a substantial reduction in casualties compared to the unshielded estimates. Other investigators have estimated that the reduction in burn injuries may be greater than 90% due to shadowing and the indoor location of most of the population [6].

We have shown that common estimates of weapon effects that calculate a "radius" for thermal radiation are clearly misleading for surface bursts in urban environments. In many cases only a few unshadowed vertical surfaces, a small fraction of the area within a thermal damage radius, receive the expected heat flux.

In future work, our code could be extended to tally the total surface area receiving various amounts of heat, and to account for reflected radiation.

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5. http://www.esri.com/

6. L. Davisson and M. Dombroski, private communication; "Radiological and Nuclear Response and Recovery Workshop: Nuclear Weapon Effects in an Urban Environment 2007," M. Dombroski, B. Buddemeier, R. Wheeler, L. Davisson, T. Edmunds, L. Brandt, R. Allen, L. Klennert, and K. Law, UCRL-TR-XXXX (2007), in review.

# *The Effects of*

# Nuclear Weapons

SAMUEL GLASSTONE
*Editor*

*Revised Edition*
*Reprinted February 1964*

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UNITED STATES DEPARTMENT OF DEFENSE
*Published by the*
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April 1962

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# Foreword

This book is a revision of "The Effects of Nuclear Weapons" which was issued in 1957. It was prepared by the Defense Atomic Support Agency of the Department of Defense in coordination with other cognizant governmental agencies and was published by the U.S. Atomic Energy Commission. Although the complex nature of nuclear weapons effects does not always allow exact evaluation, the conclusions reached herein represent the combined judgment of a number of the most competent scientists working on the problem.

There is a need for widespread public understanding of the best information available on the effects of nuclear weapons. The purpose of this book is to present as accurately as possible, within the limits of national security, a comprehensive summary of this information.

Secretary of Defense

Chairman
Atomic Energy Commission

Figure 7.33a. Thermal effects on wood-frame house 1 second after explosion (about 25 cal/sq cm).

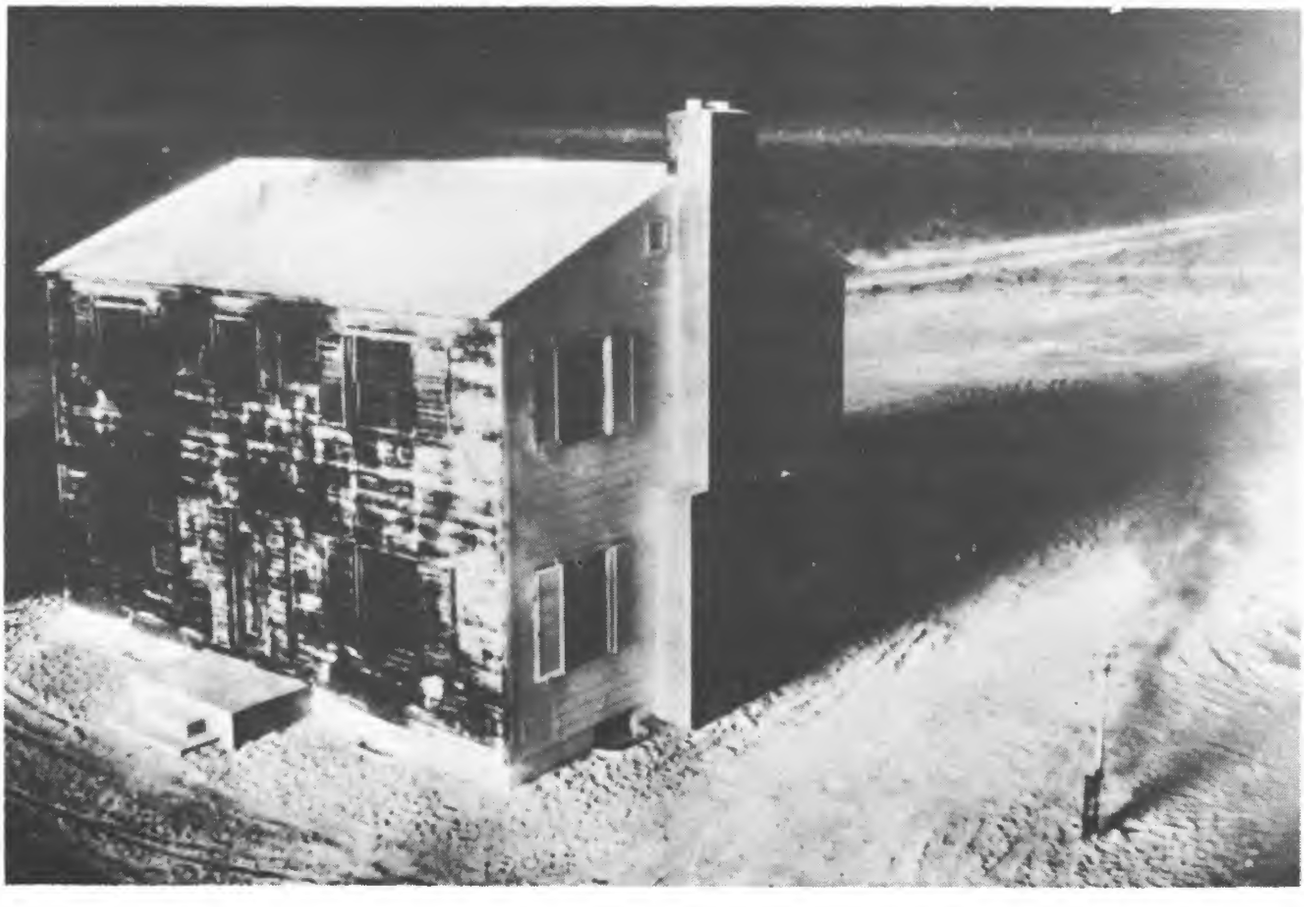


Figure 7.33b. Thermal effects on wood-frame house about ¾ second later.

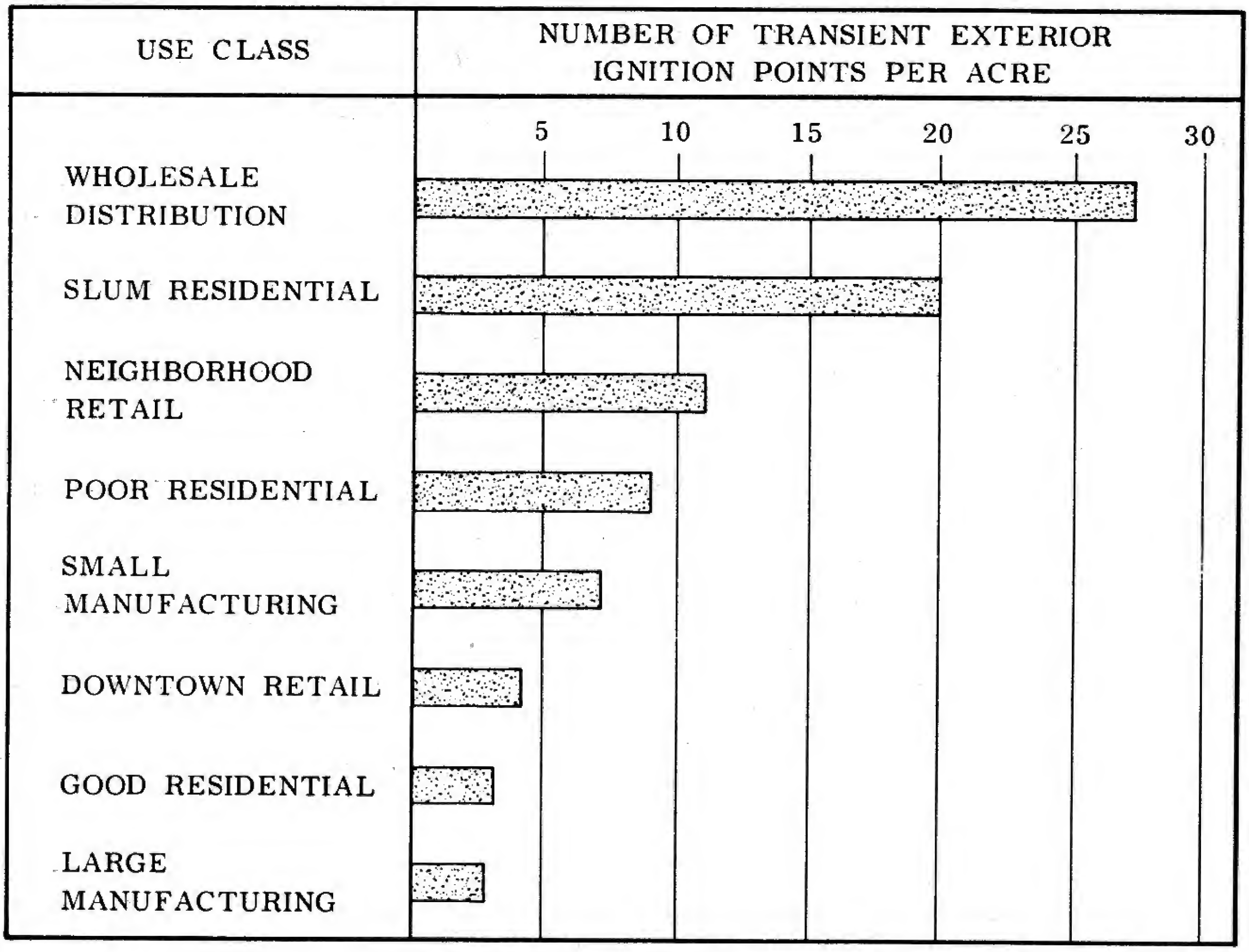



Figure 7.55. Frequency of exterior ignition points for various areas in a city

the formation of a significant fire, capable of spreading, will require appreciable quantities of combustible material close by, and this may not always be available.

7.57 The fact that accumulations of ignitable trash close to a wooden structure represent a real fire hazard was demonstrated at the nuclear tests carried out in Nevada in 1953. In these tests, three miniature wooden houses, each having a yard enclosed with a wooden fence, were exposed to 12 calories per square centimeter of thermal radiation. One house, at the left of Fig. 7.57, had weathered siding showing considerable decay, but the yard was free from trash. The next house also had a clean yard and in addition, the exterior siding was well maintained and painted. In the third house, at the right of the photograph, the siding, which was poorly maintained, was weathered, and the yard was littered with trash.

7.58 The state of the three houses after the explosion is seen in Fig. 7.58. The third house, at the right, soon burst into flame and was burned to the ground. The first house, on the left, did ignite but it did not burst into flame for 15 minutes. The well maintained house in the center with the clean yard suffered scorching only. It is of interest to recall that the wood of a newly erected white-painted

Figure 7.57. Wooden test houses before exposure to a nuclear explosion, Nevada Test Site.

Figure 7.58. Wooden test houses after exposure to a nuclear explosion.

house exposed to about 25 calories per square centimeter was badly charred but did not ignite (see Fig. 7.33b).

7.59 The value of fire-resistive furnishing in decreasing the number of ignition points was also demonstrated in the tests. Two identical, sturdily constructed houses, each having a window 4 feet by 6 feet facing the point of burst, were erected where the thermal radiation exposure was 17 calories per square centimeter. One of the houses contained rayon drapery, cotton rugs, and clothing, and, as was expected, it burst into flame immediately after the explosion and burned completely. In the other house, the draperies were of vinyl plastic, and rugs and clothing were made of wool. Although much ignition occurred, the recovery party, entering an hour after the explosion, was able to extinguish the fires.



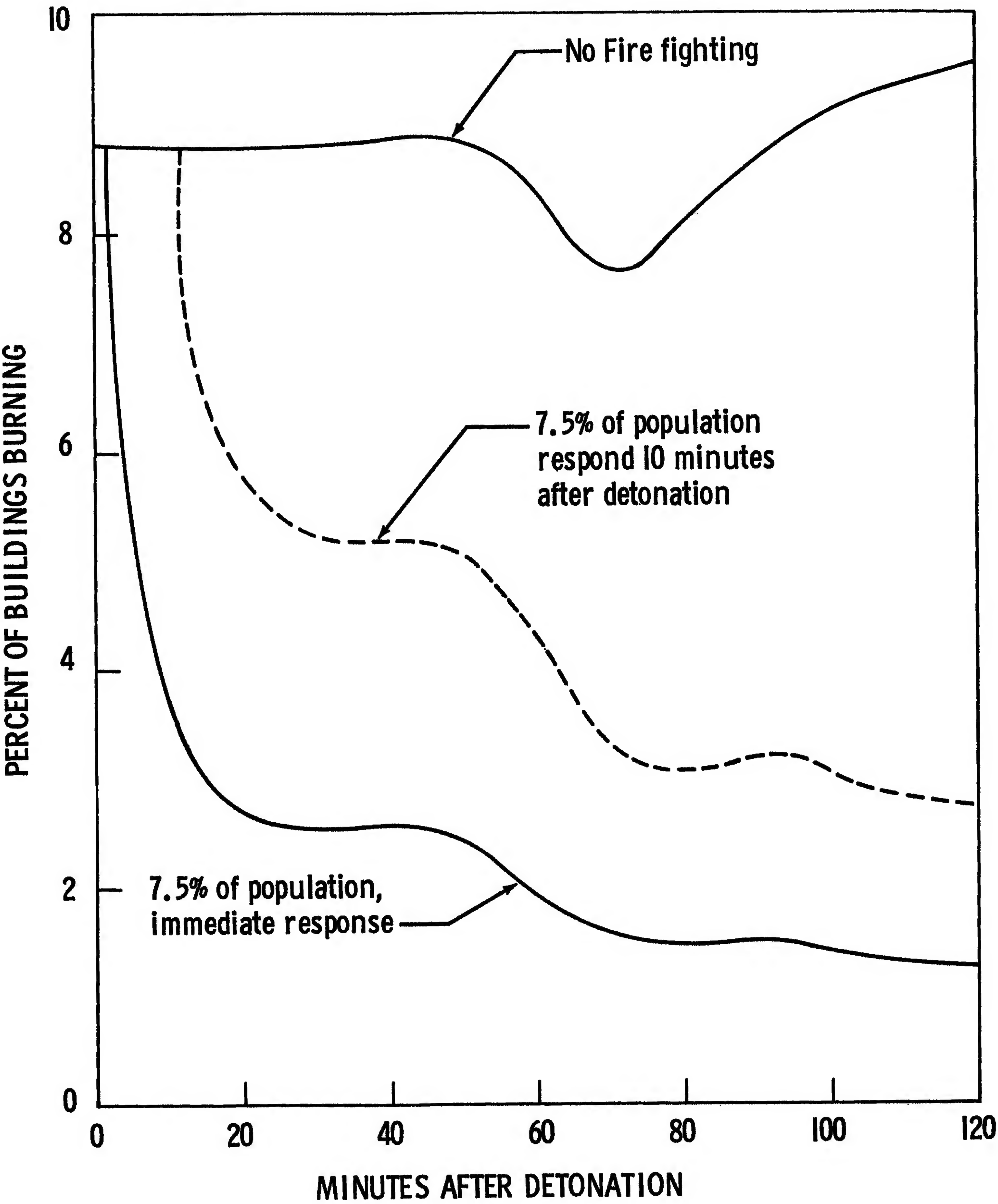
7.76 It should be noted that the fire storm is by no means a special characteristic of nuclear weapons. Similar fire storms have been reported as accompanying large forest fires in the United States, and especially after incendiary bomb attacks in both Germany and Japan during World War II. The high winds are produced largely by the updraft of the heated air over an extensive burning area. They are thus the equivalent, on a very large scale, of the draft of a chimney under which a fire is burning. Because of limited experience, the conditions for the development of fire storms in cities are not well known. It appears, however, that some, although not necessarily all, of the essential requirements are the following: (1) thousands of nearly simultaneous ignitions over an area of at least a square mile, (2) heavy building density, e.g., more than 20 percent of the area is covered by buildings, and (3) little or no ground wind. Based on these criteria, only certain sections—usually the older and slum areas—of a very few cities in the United States would be susceptible to fire storm development.



12.35. The major part of the thermal radiation travels in straight lines, and so any opaque object interposed between the fireball and the exposed skin will give some protection. This is true even if the object is subsequently destroyed by the blast, since the main thermal radiation pulse is over before the arrival of the blast wave.

12.36 At the first indication of a nuclear explosion, by a sudden increase in the general illumination, a person inside a building should immediately fall prone, as described in § 12.30, and, if possible, crawl behind or beneath a table or desk or to a planned vantage point. Even if this action is not taken soon enough to reduce the thermal radiation exposure greatly, it will minimize the displacement effect of the blast wave and provide a partial shield against splintered glass and other flying debris. An individual caught in the open should fall prone to the ground in the same way, while making an effort to shade exposed parts of the body. Getting behind a tree, building, fence, ditch, bank, or any structure which prevents a direct line of sight between the person and the fireball, if possible, will give a major degree of protection. If no substantial object is at hand, the clothed parts of the body should be used to shield parts which are exposed.

Takata, A.N., Mathematical Modeling of Fire Detenses, IITRI, March 1970, AD 705 388.



# *The Effects of*

# Nuclear Weapons

SAMUEL GLASSTONE
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*Prepared by the*
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June 1957

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Washington 25, D. C. - Price $2.00 (paper bound)

TABLE 3.11

OVERPRESSURE, DYNAMIC PRESSURE, AND WIND VELOCITY IN AIR AT SEA LEVEL

| *Peak overpressure (pounds per square inch)* | *Peak dynamic pressure (pounds per square inch)* | *Maximum wind velocity (miles per hour)* |
|---|---|---|
| 72 | 80 | 1, 170 |
| 50 | 40 | 940 |
| 30 | 16 | 670 |
| 20 | 8 | 470 |
| 10 | 2 | 290 |
| 5 | 0. 7 | 160 |
| 2 | 0. 1 | 70 |

3.12 At a given location, the dynamic pressure changes with time in a manner somewhat similar to the change in the overpressure, but the rate of pressure decrease behind the shock front is different. This may be seen from Fig. 3.12 which indicates qualitatively how the two pressures vary in the course of the first second or so following arrival of the shock front.

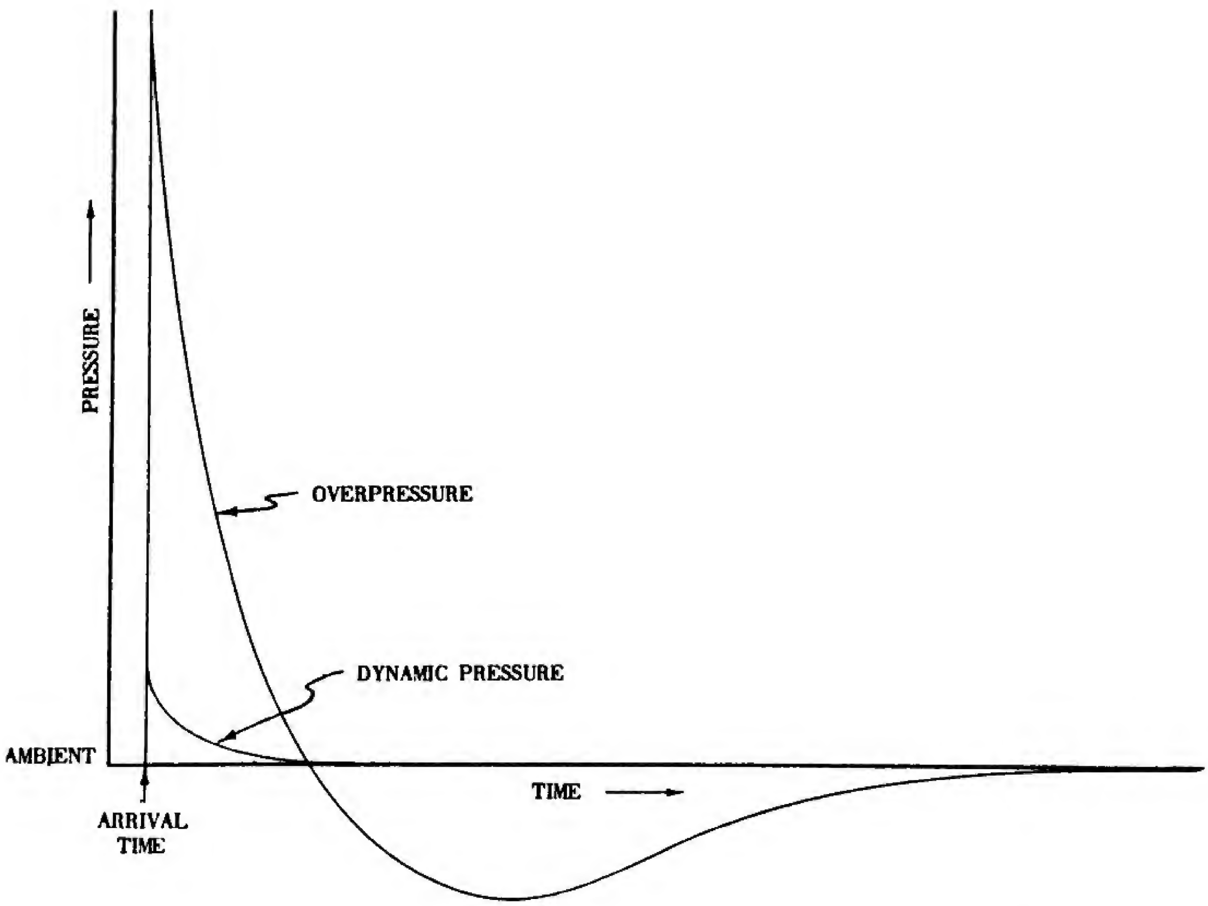



Figure 3.12. Variation of overpressure and dynamic pressure with time at a fixed location.

The curves show the variation of peak overpressure with distance for a 1 KT surface burst and for a 1 KT free-air burst (based on the $2W$ assumption in § 3.94) in a standard sea level atmosphere.

*Scaling.* For yields other than 1 KT, the range to which a given overpressure extends scales as the cube root of the yield, i. e.,

$$d = d_0 \times W^{1/3},$$

where, for a given overpressure,

$d_0$ is the distance from the explosion for 1 KT,

and

$d$ is the distance from the explosion for $W$ KT.

*Example*

*Given:* A 1 MT surface burst.

*Find:* The distance to which 2 psi extends.

*Solution:* From Fig. 3.93 the cube root of 1000 is 10. From Fig. 3.94a, a peak overpressure of 2 psi occurs at a distance of 0.53 mile from a 1 KT surface burst. Therefore, for a 1 MT surface burst,

$$d = d_0 \times W^{1/3} = 0.53 \times 10 = 5.3 \text{ miles.} \quad \textit{Answer}$$

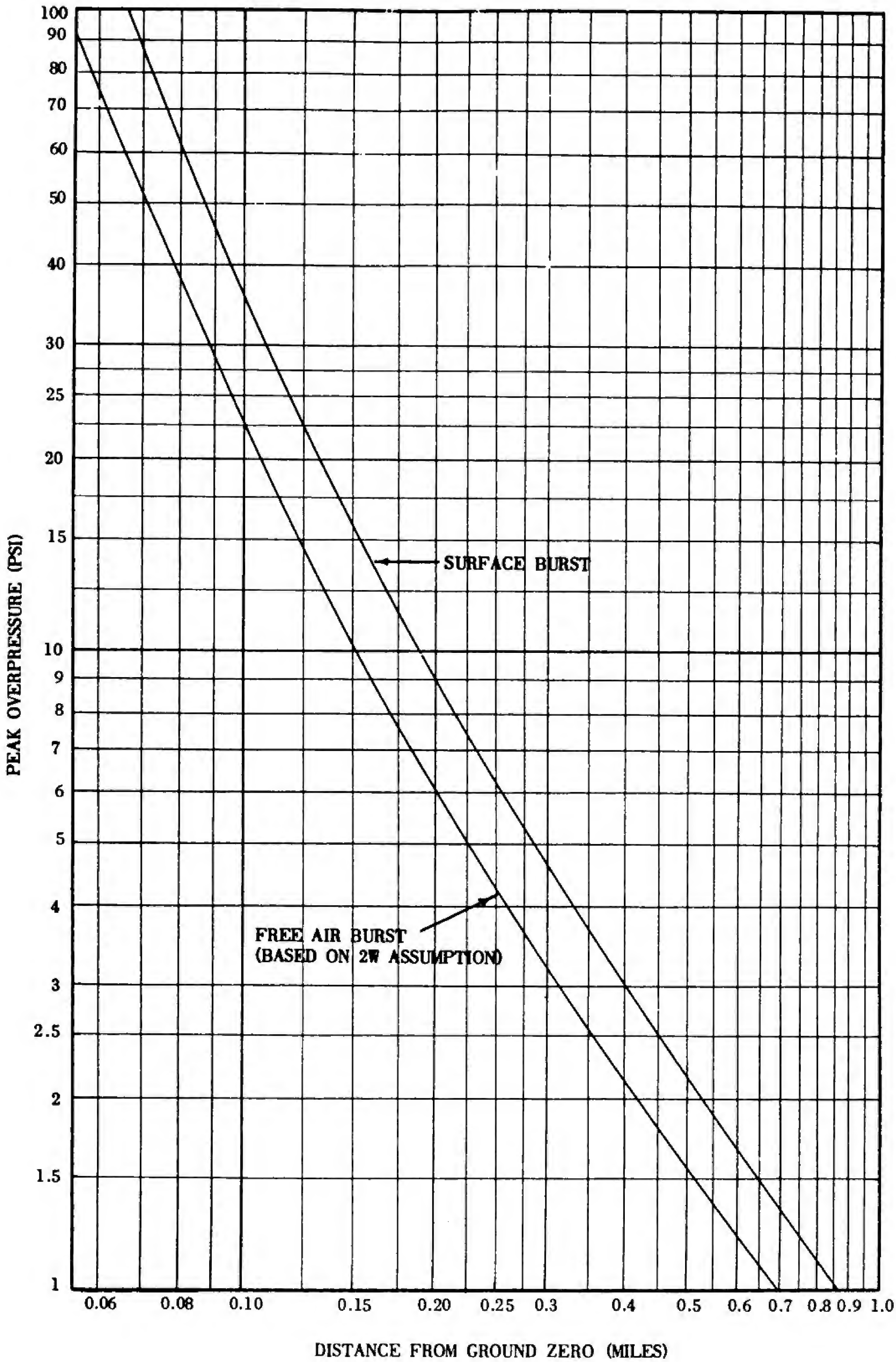



Figure 3.94a. Peak overpressure for a 1-kiloton surface burst and free air burst.

TABLE 6.12

DAMAGE CRITERIA FOR SHALLOW BURIED OR EARTH COVERED SURFACE STRUCTURES

| Type of structure | Damage class | Peak overpressure (psi) | Nature of damage |
|---|---|---|---|
| Light, corrugated steel arch, surface structure (10-gage corrugated steel with a span of 20 to 25 feet) with 3 feet of earth cover over the crown. | A | 35–40 | Complete collapse. |
| | B | 30–35 | Collapse of portion of arch facing blast. |
| | C | 20–25 | Deformation of end walls and arch, possible entrance door damage. |
| | D | 10–15 | Possible damage to ventilation system and entrance door. |
| Light, reinforced-concrete surface or underground shelter with 3 feet minimum earth cover. (Panels 2 to 3 inches thick, with beams spaced on 4-foot centers.) | A | 30–35 | Collapse. |
| | B | 25–30 | Partial collapse. |
| | C | 15–25 | Deformation, severe cracking and spalling of panels. |
| | D | 10–15 | Cracking of panels, possible entrance door damage. |

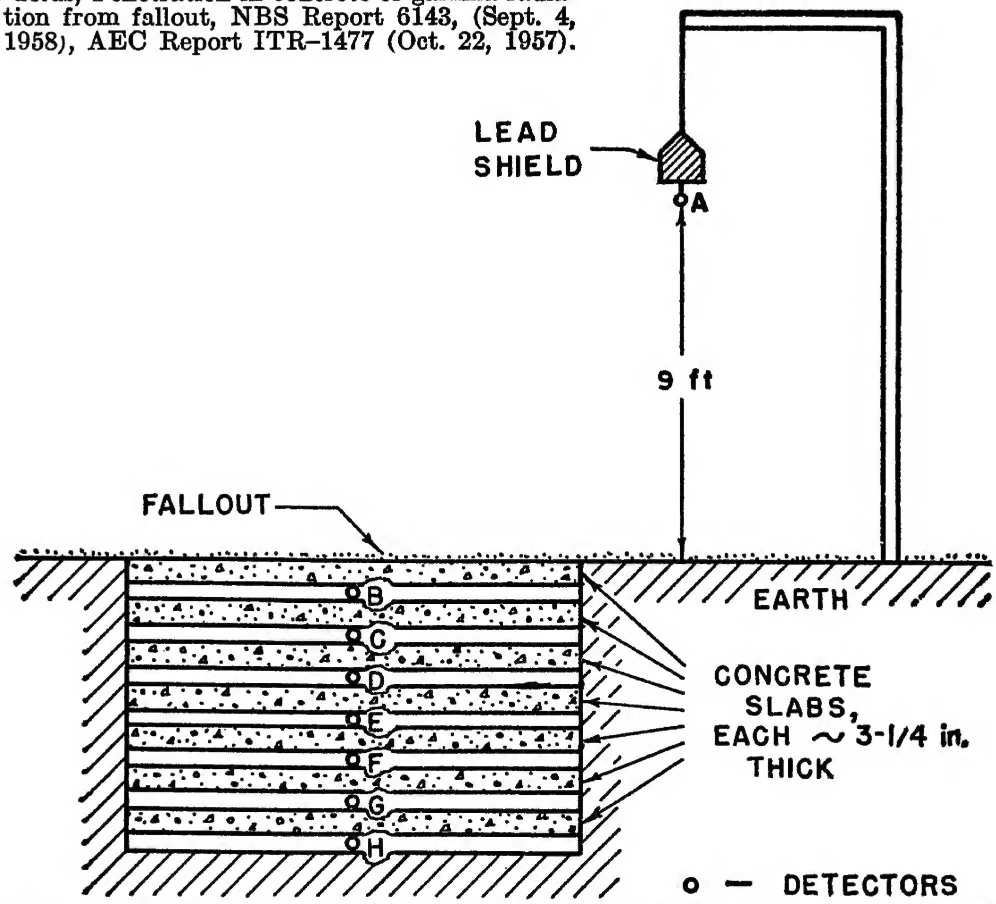
6.13 An illustration of B-type damage to a 10-gage corrugated steel-arch, earth-covered, surface structure is shown in Fig. 6.13. It will be noted that about half of the arch has collapsed. This failure was attributed primarily to the dynamic pressure acting on the forward slope of the earth mound.

6.14 The peak overpressure for the complete collapse of the corrugated steel-arch structure, with 3 feet of earth cover, is given in Table 6.12 as 35 to 40 pounds per square inch. However, it has been estimated that if this structure had been completely buried, so that no earth mound was required, an overpressure of 40 to 50 pounds per square inch would have been necessary to cause it to collapse. This increase in the required overpressure is due to the fact that the dynamic pressure is minimized under these conditions. It may be mentioned

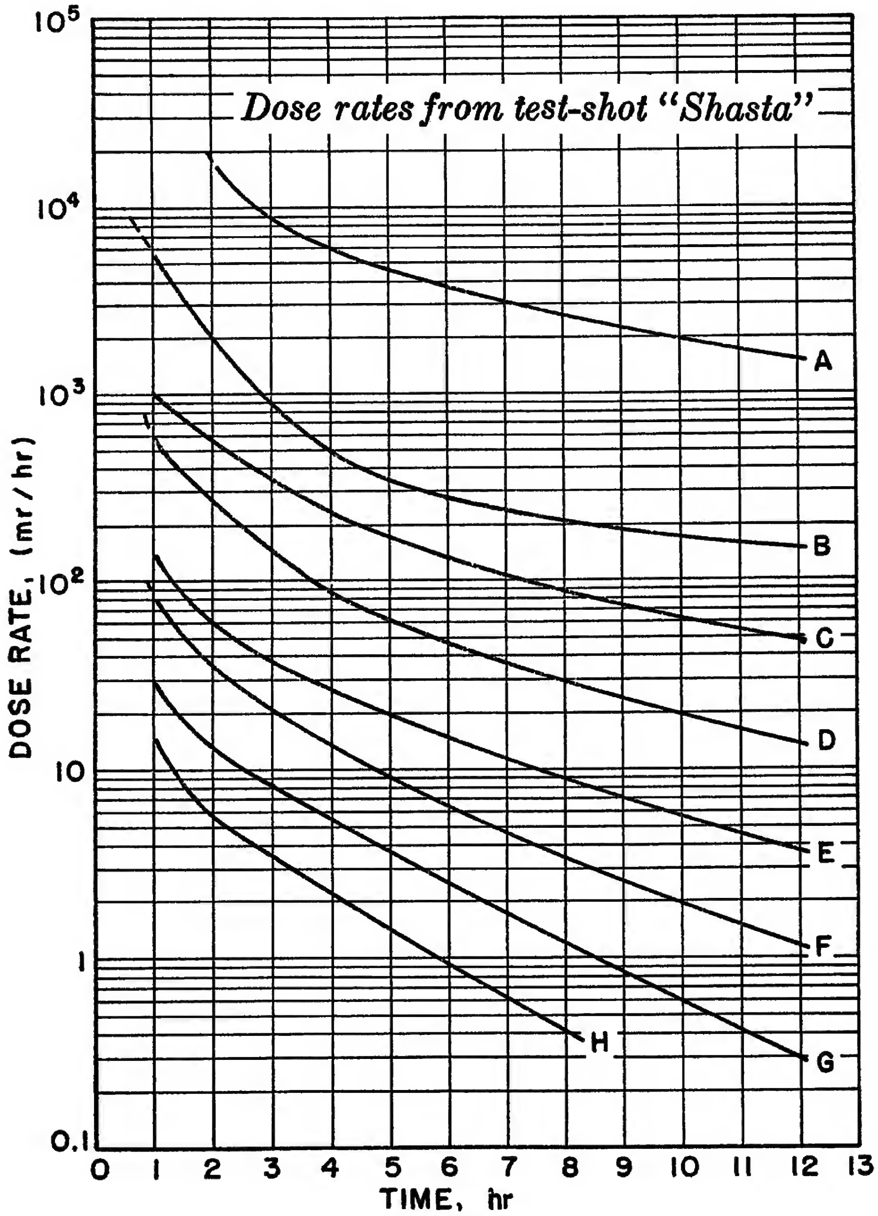
Figure 6.13. B-type damage to earth-covered 10-gage corrugated steel structure.

that, using standard engineering techniques, it is possible to design underground structures which will withstand blast overpressures in excess of 100 pounds per square inch at the surface (see Chapter XII).

F. Titus, Penetration in concrete of gamma radiation from fallout, NBS Report 6143, (Sept. 4, 1958), AEC Report ITR-1477 (Oct. 22, 1957).




The lead shield prevents fallout material from settling directly on detector "A," while at the same time shielding against the intercepted material



# CIVIL DEFENCE

## why we need it

## Message from the Home Secretary and the Secretary of State for Scotland

For over 30 years our country, with our allies, has sought to avoid war by deterring potential aggressors. Some disagree as to the means we should use. But whatever view we take, we should surely all recognise the need – and indeed the duty – to protect our civil population if an attack were to be made upon us; and therefore to prepare accordingly.

The Government is determined that United Kingdom civil defence shall go ahead. The function of civil defence is not to encourage war, or to put an acceptable face on it. It is to adapt ourselves to the reality that we at present must live with, and to prepare ourselves so that we could alleviate the suffering which war would cause if it came.

Even the strongest supporter of unilateral disarmament can consistently give equal support to civil defence, since its purpose and effect are essentially humane.

George Younger.

## Why bother with civil defence?

Why bother with wearing a seat belt in a car? Because a seat belt is reckoned to lessen the chance of serious injury in a crash. The same applies to civil defence in peacetime.

War would be horrific. Everyone knows the kind of devastation and suffering it could cause. But while war is a possibility – however slight – it is right to take measures to help the victims of an attack, whether nuclear or 'conventional'.

## But isn't it a waste of money in these days of nuclear weapons and the dreadful prospects of destruction?

No. It is money well spent if it shows people how they can safeguard themselves and their families.

## But surely there is no real protection against a nuclear attack?

Millions of lives could be saved, by safeguards against radiation especially. But civil defence is not just protection against a nuclear attack. It is protection against *any* sort of attack. NATO experts reckon that any war involving the UK is likely at least to start with non-nuclear weapons. Indeed, while no war is likely so long as we maintain a credible deterrent, the likelihood of a nuclear war is less than that of a 'conventional' one.

## But doesn't civil defence get people more war-minded, thus increasing the risk of conflict?

That is like saying people who wear seat belts are expecting to have more crashes than those who do not. Taking civil defence seriously means seeking to save lives in the catastrophe of an attack on our country.

## To Sum Up

The case for civil defence stands regardless of whether a nuclear deterrent is necessary or not. Radioactive fallout is no respecter of neutrality. Even if the UK were not itself at war, we would be as powerless to prevent fallout from a nuclear explosion crossing the sea as was King Canute to stop the tide. This is why countries with a long tradition of neutrality (such as Switzerland and Sweden) are foremost in their civil defence precautions.

# Civil defence is common sense

## Further information:

*Nuclear Weapons*
ISBN 0 11 34055 X — HMSO £3.50 (net)

*Protect and Survive*
ISBN 0 11 3407289 — HMSO 50p (net)

*Domestic Nuclear Shelters*
ISBN 0 11 3407378 — HMSO 50p (net)

*Domestic Nuclear Shelters – Technical Guidance*
ISBN 0 11 34073786 — HMSO £5.50 (net)

HOME OFFICE

SCOTTISH HOME DEPARTMENT

MANUAL OF CIVIL DEFENCE

Volume I

PAMPHLET No. 1

# NUCLEAR WEAPONS

*LONDON*

HER MAJESTY'S STATIONERY OFFICE

1956

**Practical protection**

88 Large buildings with a number of storeys, especially if they are of heavy construction, provide much better protection than small single-storey structures (see Figure 4). Houses in terraces likewise provide much better protection than isolated houses because of the shielding effect of neighbouring houses.

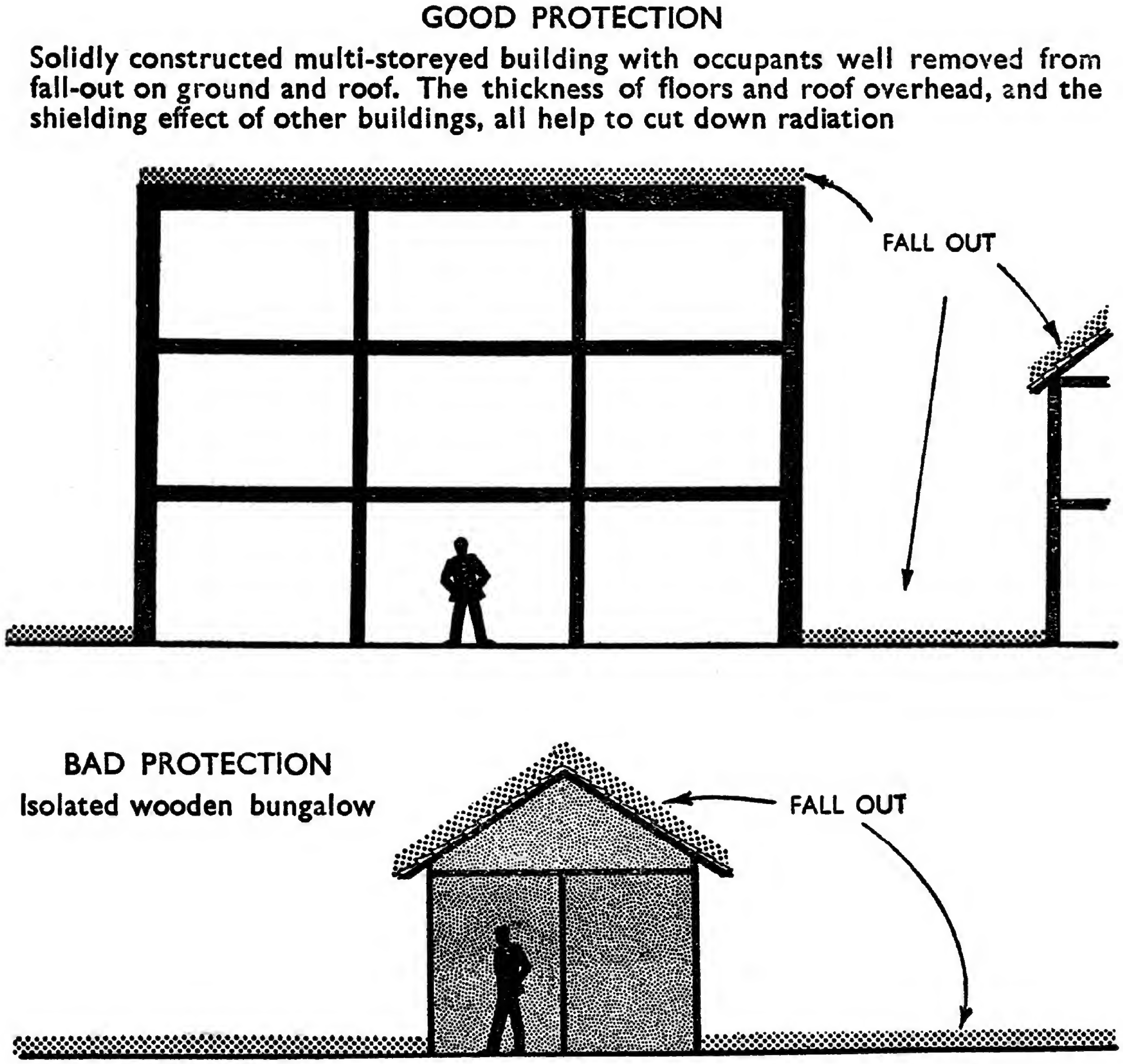



FIGURE 4

Examples of good and bad protection afforded by buildings against fall-out.

89 It is estimated that the protection factor (the factor by which the outside dose has to be divided to get the inside dose) of a ground floor room in a two-storey house ranges from 10 to about 50, depending on wall thickness and the shielding afforded by neighbouring buildings. The corresponding figures for bungalows are about 10–20, and for three-storey houses about 15–100. An average two-storey brick house in a built-up area gives a factor of 40, but basements, where the radiation from outside the house is attenuated by a very great thickness of earth, have protection factors ranging up to 200–300. A slit trench with even a light cover of boards or corrugated iron without earth overhead gives a factor of 7, and if 1 ft. of earth cover is added the

factor rises to 100. If the trench can be covered with 2 or 3 feet of earth then a factor of more than 200–300 can be obtained (see Figure 5).

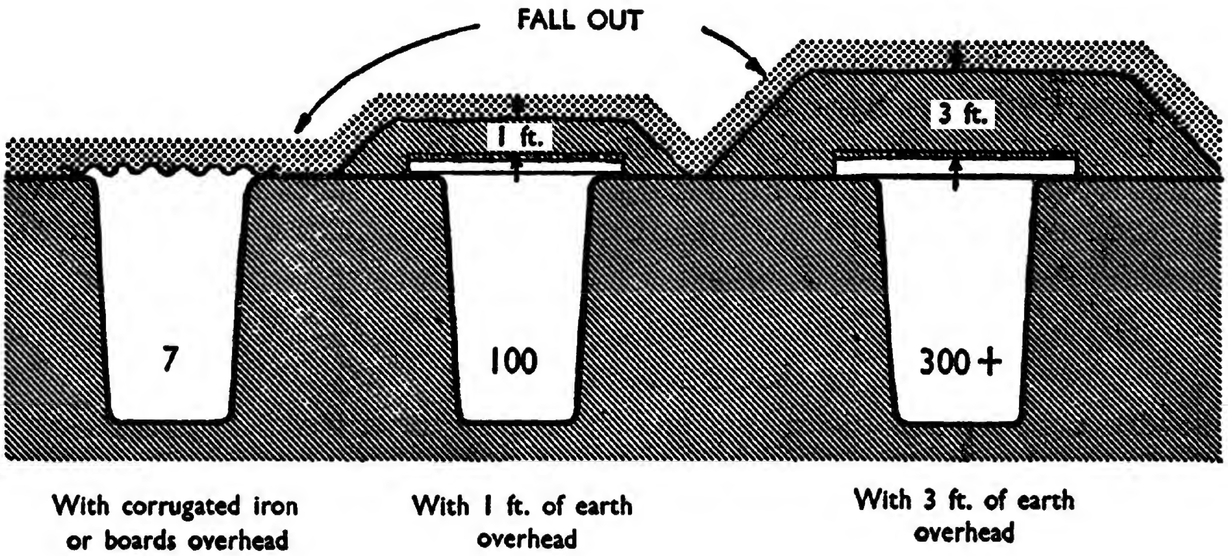



FIGURE 5
Protection factors in slit trenches (the factor by which the outside dose is divided to get the inside dose).

### Choosing a refuge room

90 In choosing a refuge room in a house one would select a room with a minimum of outside walls and make every effort to improve the protection of such outside walls as there were. In particular the windows would have to be blocked up, e.g. with sandbags. Where possible, boxes of earth could be placed round an outside wall to provide additional protection, and heavy furniture (pianos, bookcases etc.) along the inside of the wall would also help. A cellar would be ideal. Where the ground floor of the house consists of boards and timber joists carried on sleeper walls it may be possible to combine the high protection of the slit trench with some of the comforts of the refuge room by constructing a trench under the floor.
Once a trap door had been cut in the floor boards and joists and the trench had been dug, there would be no further interference with the peace-time use of the room.

### Estimated under-cover doses in the fall-out area

91 Taking an average protective factor of 40 for a two-storey house in a built-up area, the doses accumulated in 36 hours for the ranges referred to in the U.S. Atomic Energy Commission Report (paragraph 84) would have been:—

| | | |
|---|---|---|
| 190 miles downwind | | 7½r |
| 160 ,, | ,, | 12½r |
| 140 ,, | ,, | 20r |

15 Megatons
Bravo 1954

which are all well below the lowest figure of 25r referred to in Table 1. At closer ranges along the axis of the fall-out, the doses accumulated in 36 hours would have been much higher, but over most of the contaminated area—with this standard of protection—the majority of those affected would have been saved from death, and even from sickness, by taking cover continuously for the first 36 hours.

5. **Radiation sickness**

Assume dose incurred in a single shift (3–4 hours) by the "average" man, over the whole body:—

| | |
|---|---|
| 25 roentgens | —No obvious harm. |
| 100 ,, | —Some nausea and vomiting. |
| 500 ,, | —Lethal to about 50 per cent. people (death up to 6 weeks later). |
| 800 ,, or more | —Lethal to all (death up to 6 weeks later). |

*Note:* If dose spread uniformly over 2–3 days, then 60 roentgens could be incurred with no more effect than 25 roentgens in a single exposure of 3–4 hours.

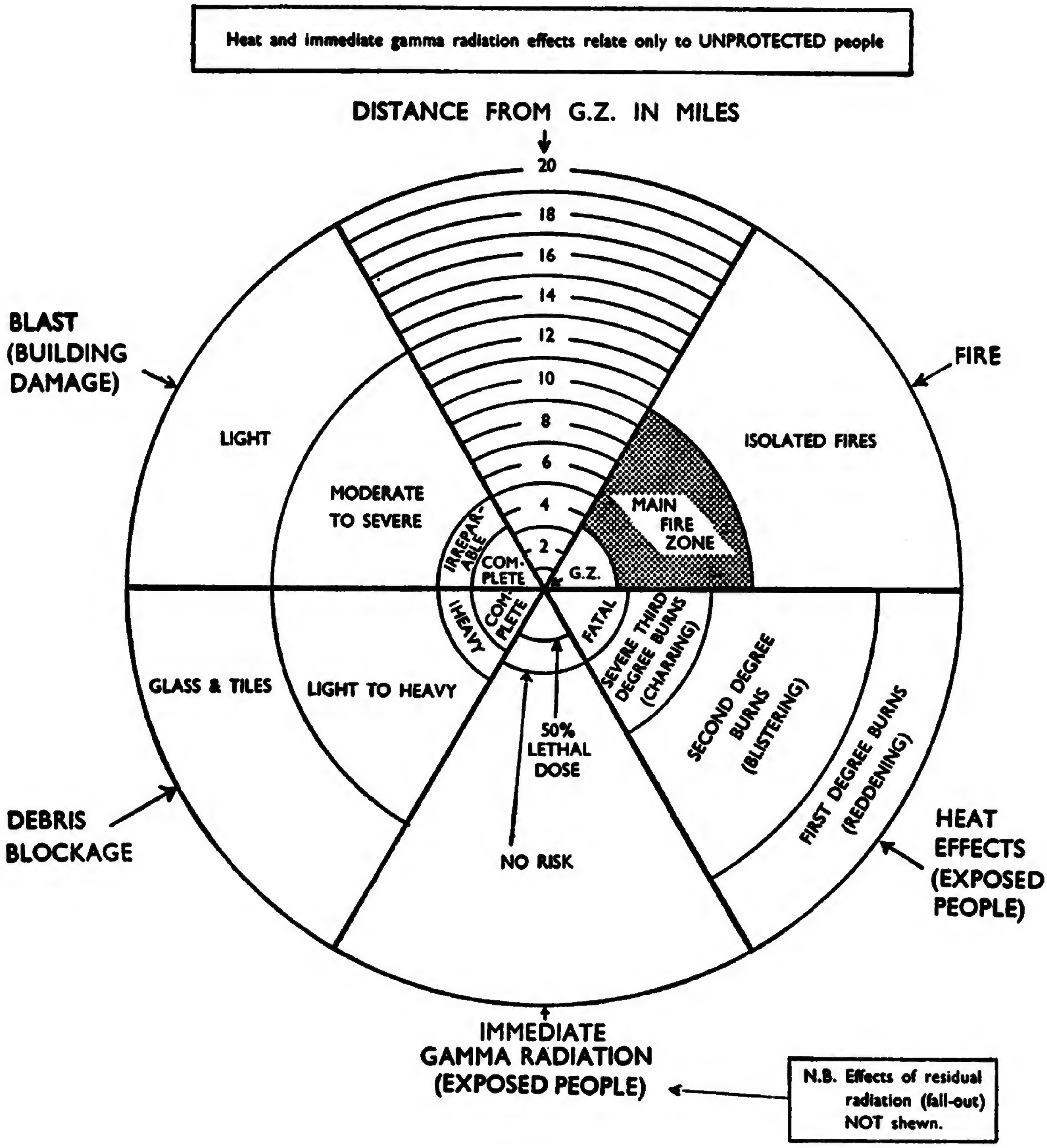



FIGURE 11

Combined effects (excluding residual radioactivity) from a 10 megaton ground burst bomb. Heat and immediate gamma radiation effects relate only to UNPROTECTED people.

## A Fallout Forecasting Technique With Results Obtained at the Eniwetok Proving Ground

E. A. Schuert, USNRDL TR-139, United States Naval Radiological Defense Laboratory, San Francisco, Calif.

### ADMINISTRATIVE INFORMATION

The work described herein is a part of the research sponsored by BuShips and the United States Army and locally designated as program 2, problem 3, phase 3. Its technical objective is AW-7 and it is described on RDB card NS 081-001.

### SUMMARY

The problem: A fallout forecasting technique is needed to qualitatively describe the fallout hazard resulting from nuclear detonations. This technique should have such flexibility that its employment is valid for field use.

Findings: A summary of the latest experimental and theoretical considerations has resulted in the development of a technique whose complexity is dependent on the required accuracy of the results desired. This technique has been satisfactorily tested at the Eniwetok Proving Grounds for land surface and water surface bursts.

*Particle size distribution in source model*

All particle sizes were assumed at all elevations within the cloud except the lower two-thirds of the stem. However, to obtain agreement with past fallout measurements and with the optical diameter of the mushroom, it was necessary to fractionate the particle size distribution radially within the cloud. Otherwise, the computed fallout area about ground zero would be too large. The fractionation was specified as follows: particles of 1,000 microns in diameter and larger were restricted to the inner 10 percent of the mushroom radius or approximately the stem radius; those from 500 to 1,000 microns in diameter were limited to the inner 50 percent of the cloud radius. Since the relation of activity to particle size is some function of the particle diameter this fractionation tends to concentrate the activity about the axis of symmetry of the cloud.

***Falling speeds*** **(feet/hour)**

J. M. Dallavalle, Mircomeritics, Pittman Publishing Corp., 1948.

| Altitude | 75 $\mu$ | 100 $\mu$ | 200 $\mu$ | 350 $\mu$ | Altitude | 75 $\mu$ | 100 $\mu$ | 200 $\mu$ | 350 $\mu$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 3,060 | 5,040 | 11,700 | 21,600 | 65 | 4,190 | 7,480 | 26,100 | 51,100 |
| 5 | 3,120 | 5,240 | 12,300 | 22,900 | 70 | 4,110 | 7,320 | 27,600 | 55,200 |
| 10 | 3,200 | 5,480 | 12,900 | 24,100 | 75 | 4,010 | 7,150 | 28,100 | 59,700 |
| 15 | 3,270 | 5,750 | 13,700 | 25,500 | 80 | 3,910 | 6,960 | 27,800 | 61,900 |
| 20 | 3,360 | 5,980 | 14,400 | 27,100 | 85 | 3,800 | 6,770 | 27,100 | 67,800 |
| 25 | 3,470 | 6,160 | 15,300 | 28,800 | 90 | 3,720 | 6,640 | 26,500 | 71,300 |
| 30 | 3,570 | 6,380 | 16,300 | 30,800 | 95 | 3,620 | 6,470 | 25,800 | 77,300 |
| 35 | 3,720 | 6,640 | 17,500 | 33,000 | 100 | 3,550 | 6,340 | 25,300 | 80,200 |
| 40 | 3,870 | 6,910 | 18,600 | 35,300 | 105 | 3,470 | 6,180 | 24,800 | 75,800 |
| 45 | 4,040 | 7,200 | 19,800 | 37,800 | 110 | 3,400 | 6,050 | 24,000 | 74,200 |
| 50 | 4,210 | 7,520 | 21,400 | 40,600 | 115 | 3,330 | 5,930 | 23,700 | 72,600 |
| 55 | 4,420 | 7,860 | 23,200 | 44,600 | 120 | 3,260 | 5,800 | 23,400 | 71,100 |
| 60 | 4,200 | 7,700 | 24,400 | 47,200 | | | | | |

Experimental data from past tests at Eniwetok Atoll indicated that the particles were irregular in shape and had a mean density of 2.36 g/cu cm.

*Time variation of the winds aloft*

In most of the observations made at the Eniwetok Proving Ground, the winds aloft were not in a steady state. Significant changes in the winds aloft were observed in as short a period as 3 hours. This variability was probably due to the fact that proper firing conditions which required winds that would deposit the fallout north of the proving ground, occurred only during an unstable synoptic situation of rather short duration.

The forecasting technique described was employed by the fallout program at the Eniwetok Proving Ground to satisfy certain project requirements. One project had three ships equipped to collect fallout and their positions had to be determined for most efficient collection; another sampled the ocean for fallout; while another made an aerial survey of the contaminated area. The navigational schedules for these latter projects were based on the forecast fallout pattern. Operations were controlled through the program control center aboard the task force command ship where the forecasts were prepared.

The meteorological data was received from the weather ship at Bikini Atoll as well as from weather stations at Rongerik Atoll and Eniwetok Atoll. Furthermore all forecasts made by the task force weather central at Eniwetok Atoll were usually available aboard the command ship by facsimile through the ships weather station.

Upper air measurements were made at Bikini, Rongerik, and Eniwetok Atolls every 3 hours starting at H—24 hour and continuing until H+24 hour for any given detonation. The frequency of observations was usually increased during the period from H—6 to H—2 hours. The altitudes reached on the wind runs were remarkably high and gave perhaps the best set of winds-aloft measurements to date. The average termination altitude was approximately 90,000 feet with many runs over 100,000 feet. Such excellent coverage of the winds aloft was a major help in the fallout forecasting.

Fallout forecasts were made every 3 hours starting at H—24 hour using the *measured* winds available at the time. This process was continued up to shot time and from then on the technique of correcting for time variation was employed every 3 hours until the fallout event was completed. It was not feasible to correct for space variation and vertical motions during this period because of lack of time and data.

### *Fallout plots*

The fallout forecasts determined at the weapons-test operation were based entirely on measured data and quantitatively considered time variation of the wind. No space variation corrections or computed values of vertical motions were employed in their construction.

A and B were land-surface detonations, C and D were water-surface shots.

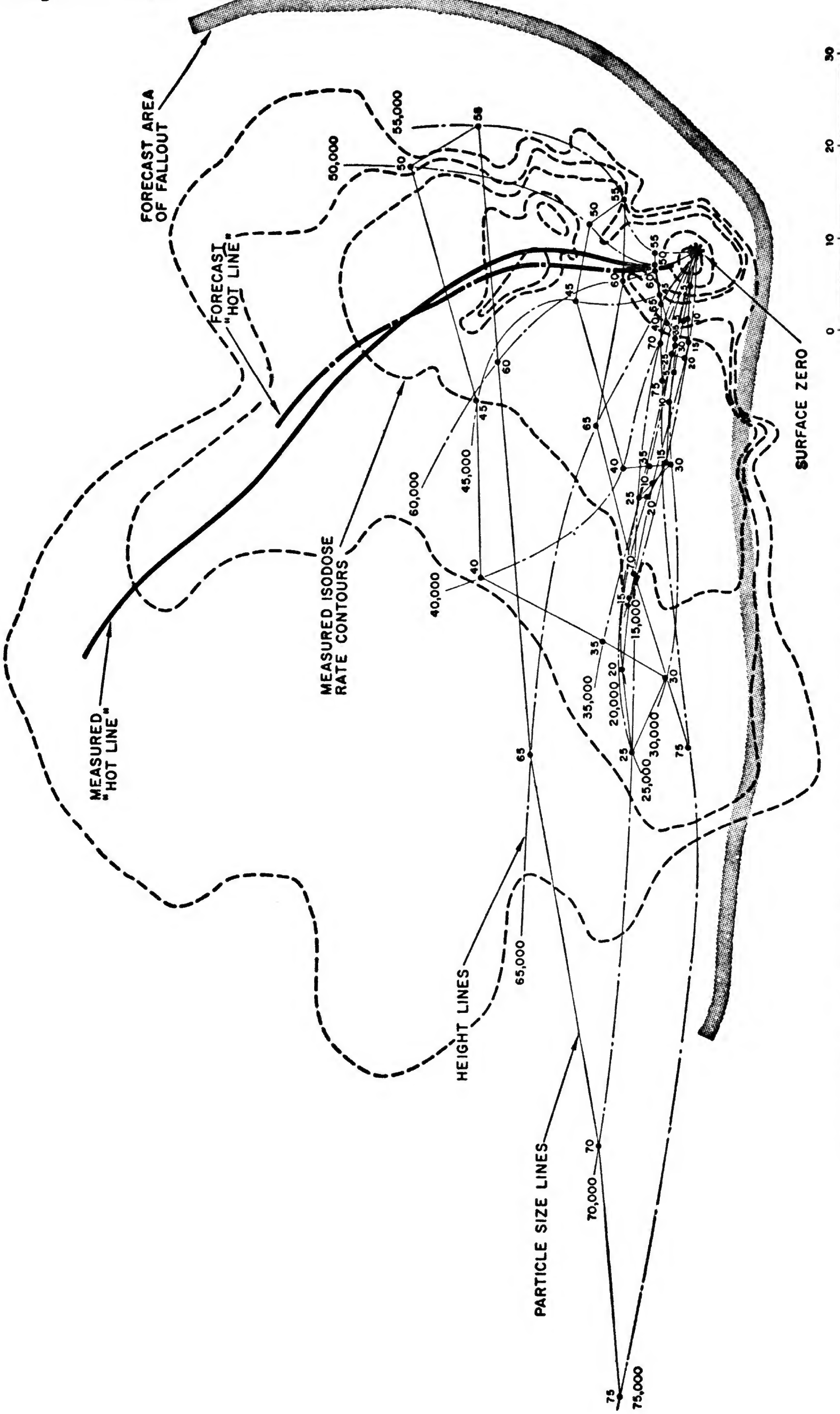
The comparison is excellent for all shots except B.

## SUMMARY

The fallout forecasting technique described in this report was successfully employed for both land surface and water surface detonations at the Eniwetok Proving Ground. With known meterological data such a technique will successfully qualify the area of fallout and indicate qualitatively the relative intensity of radiation.

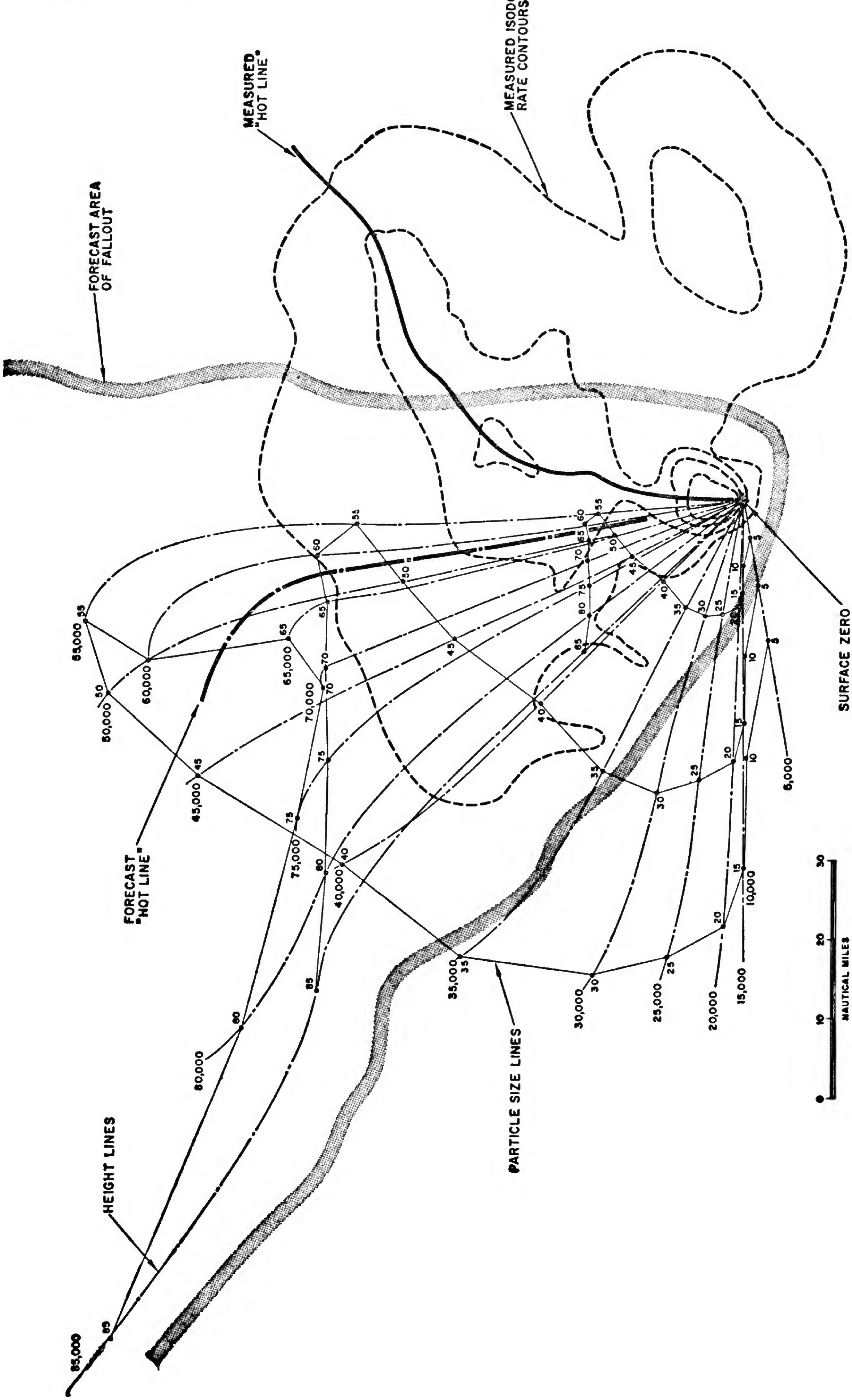
"Height lines" are deposit locations for all particles falling from a fixed altitude within the mushroom cloud. "Size lines" are deposit locations of a fixed particle size from various altitudes. A height line from the base of the mushroom disc is the "hot line".

5 megaton Tewa



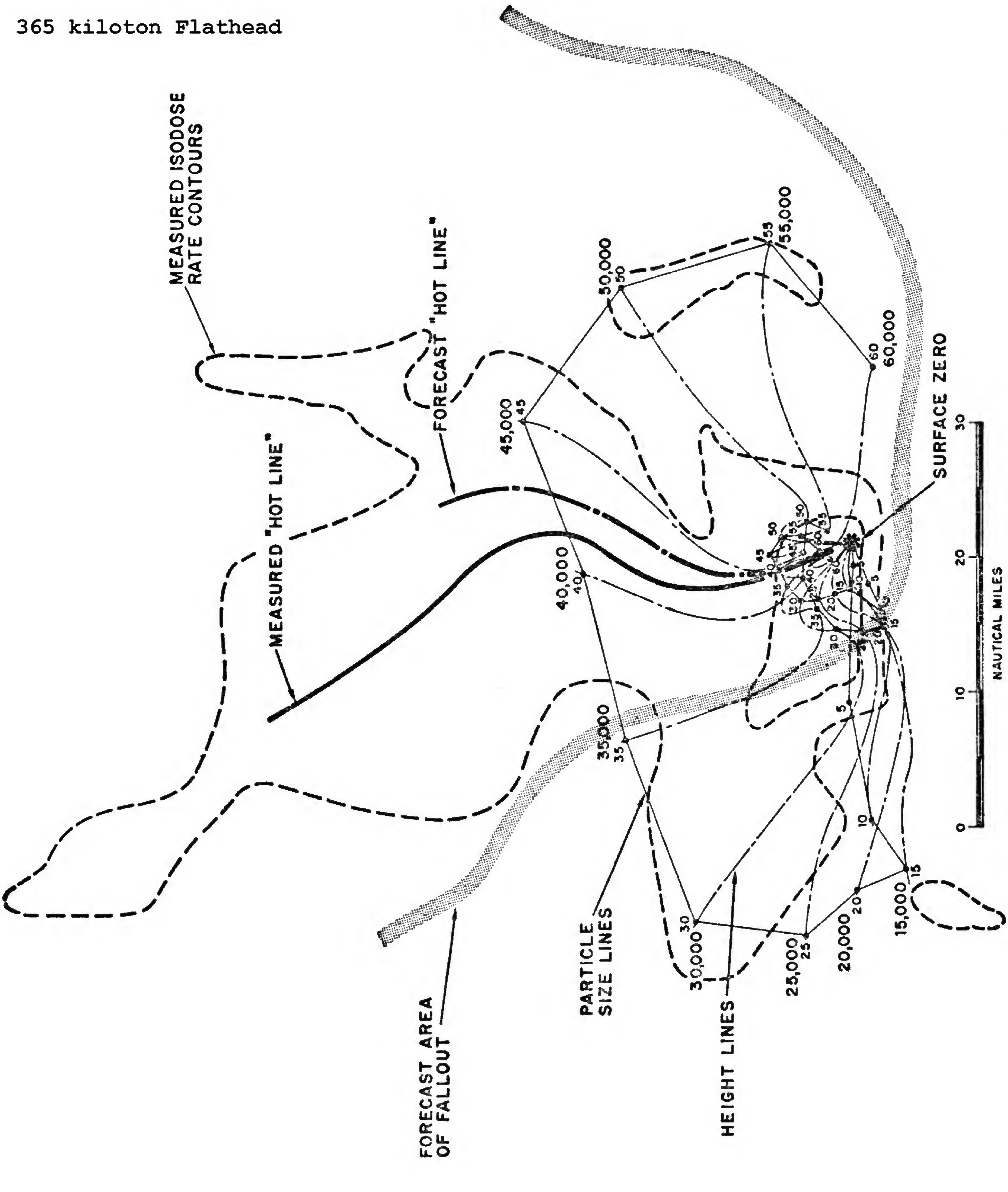

*Comparison of fallout forecast with test results—shot A*

3.5 megaton Zuni



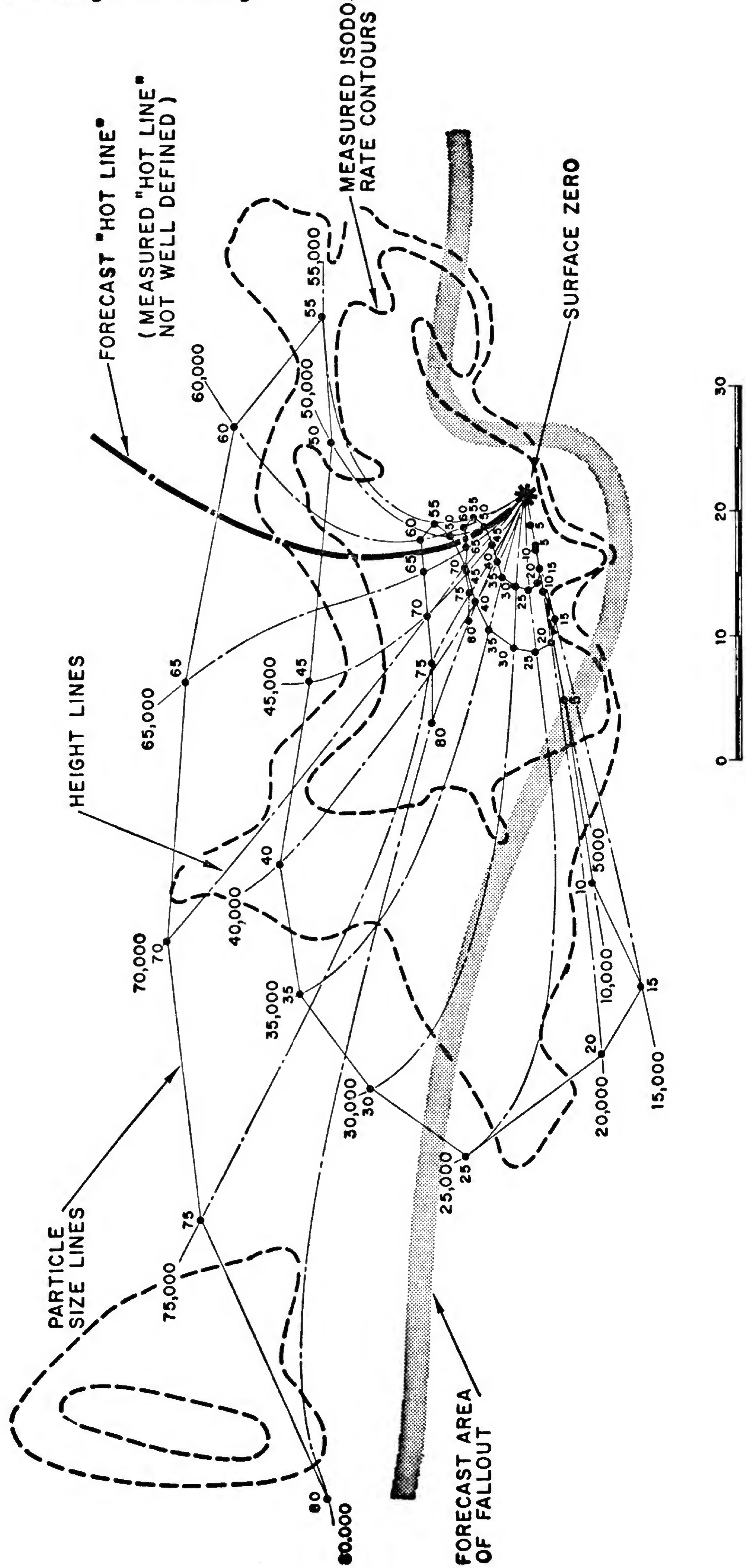

*Comparison of fallout forecast with test results—shot B.*

**365 kiloton Flathead**




*Comparison of fallout forecast with test results—shot C.*

4.5 megaton Navajo




*Comparison of fallout forecast with test results—shot D.*

SECRET

WT-615

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No. 254 of 265 copies, Series A

Report to the Scientific Director

# NATURE, INTENSITY, AND DISTRIBUTION OF FALL-OUT FROM MIKE SHOT

(The first 10 megaton H-bomb test, 1952)


By

W. B. Heidt, Jr., LCDR, USN
E. A. Schuert
W. W. Perkins
R. L. Stetson

U. S. Naval Radiological Defense Laboratory
San Francisco, California

April 1953

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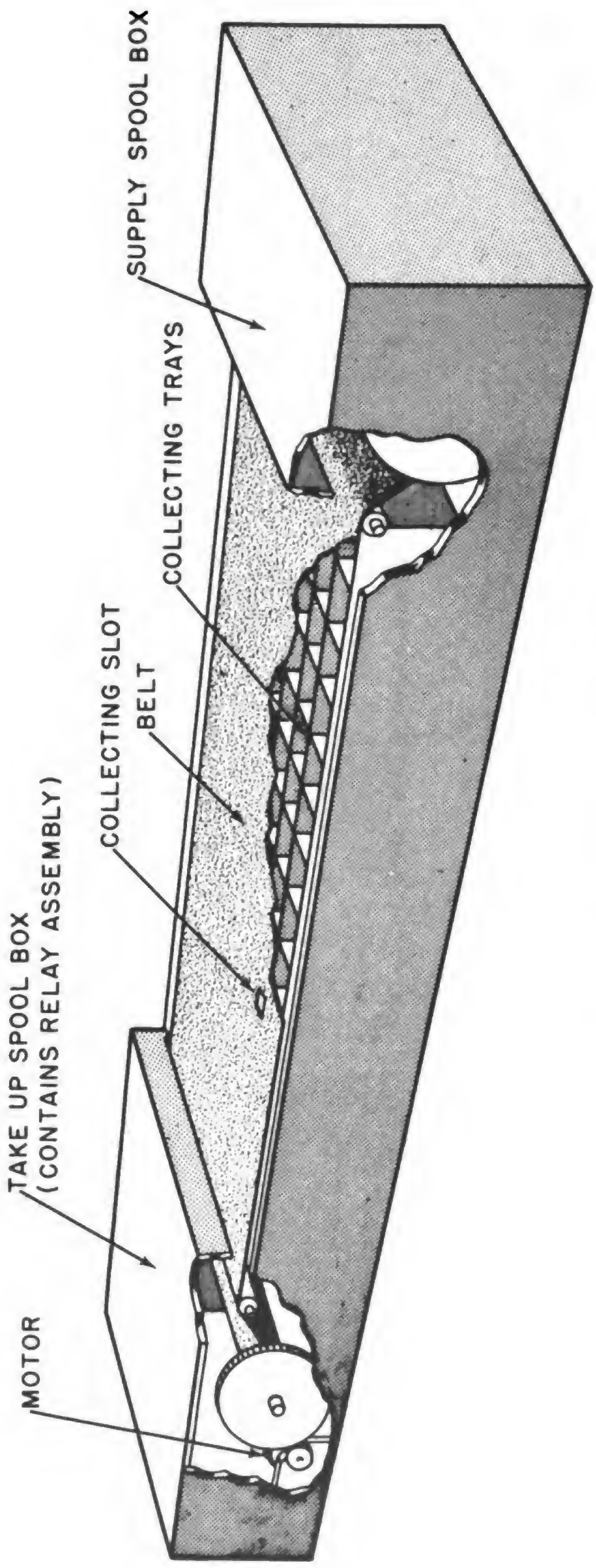



Fig. 3.2—Differential fall-out collector.

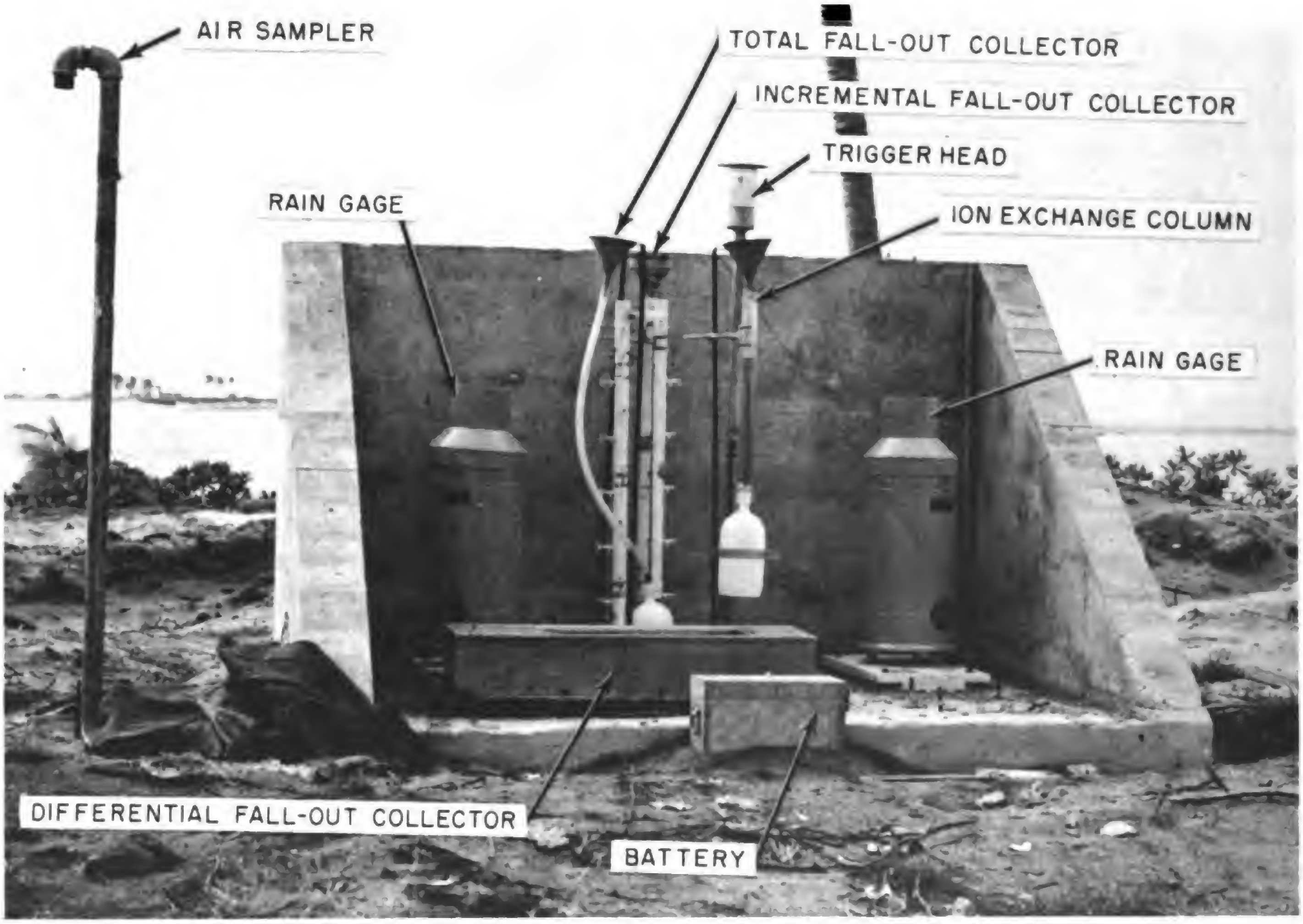



**Fig. 3.8—A typical land station.**

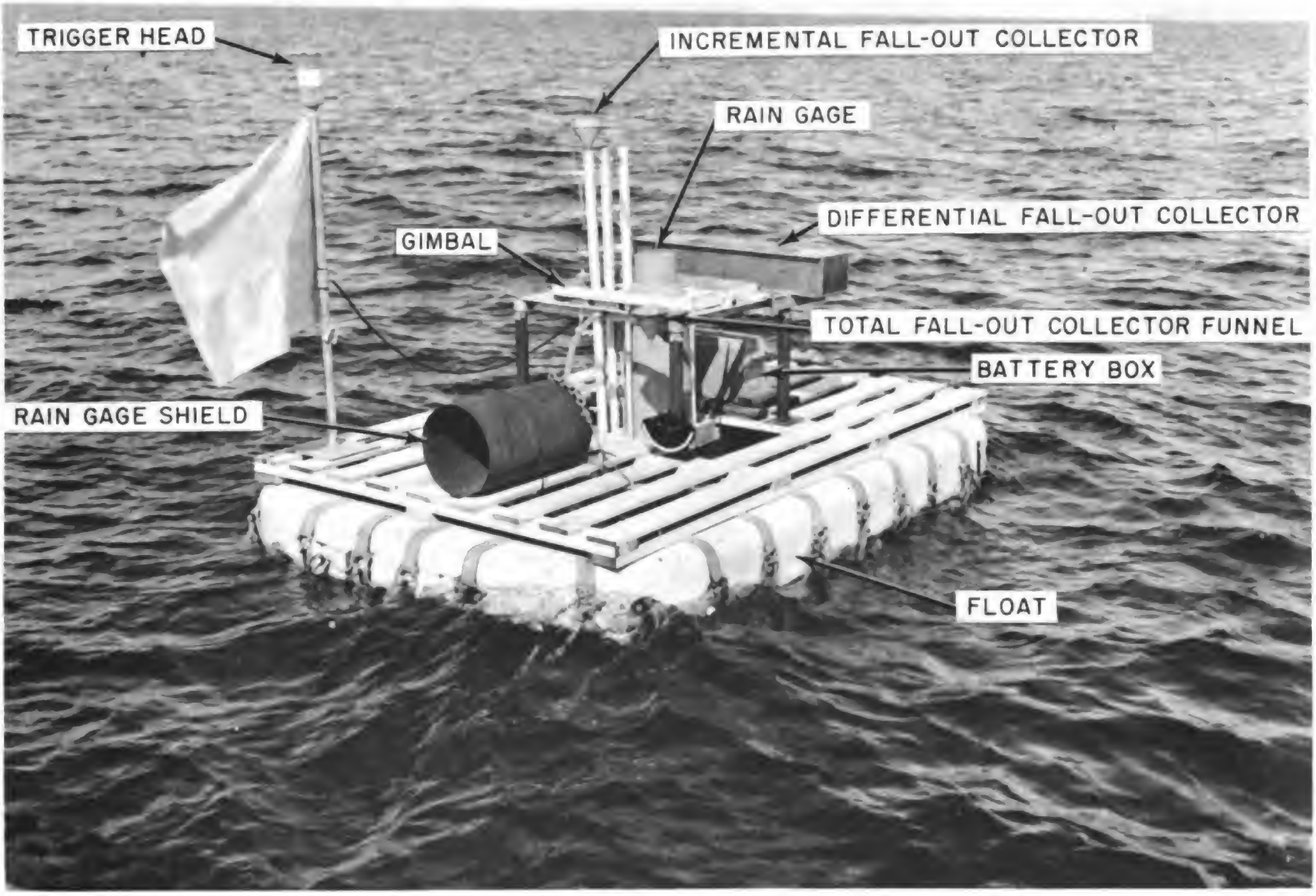
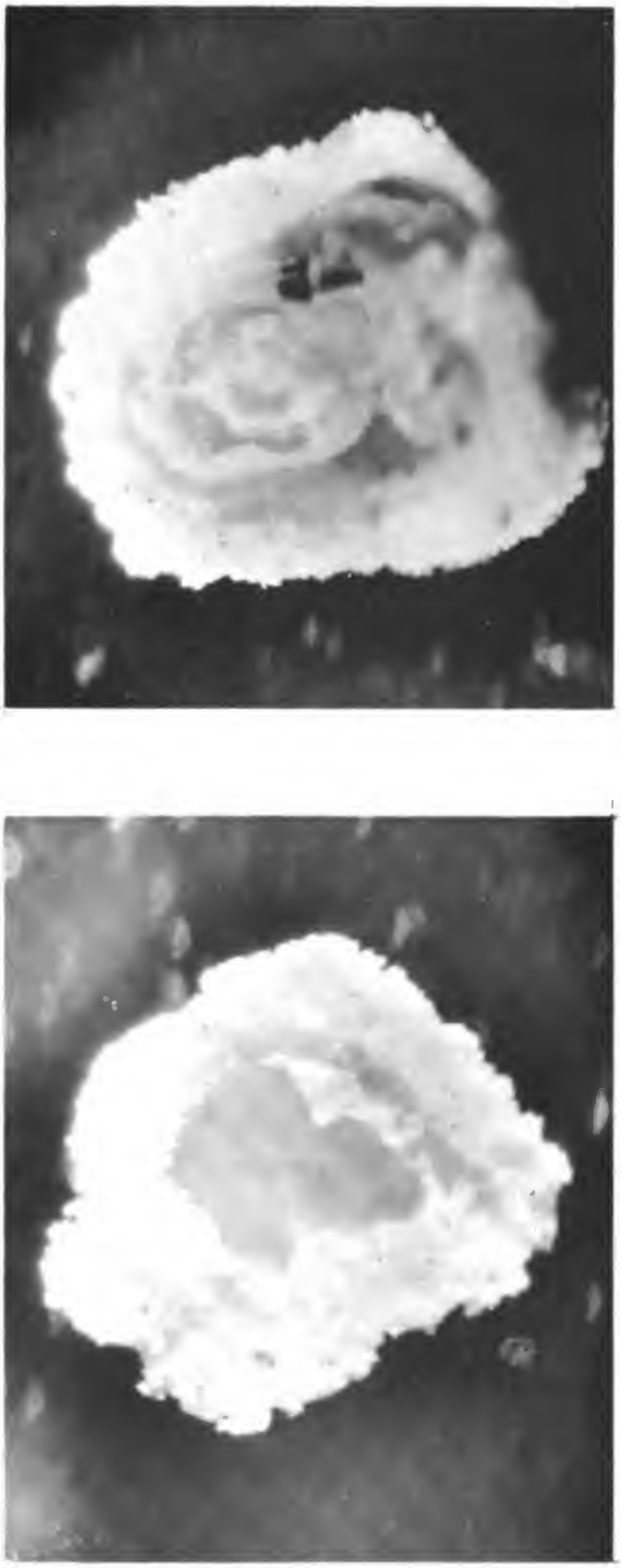



**Fig. 3.9—A typical lagoon station.**



1,000
MICRONS

Fig. 4.4—Inverted view of typical particles removed from life-float decking.

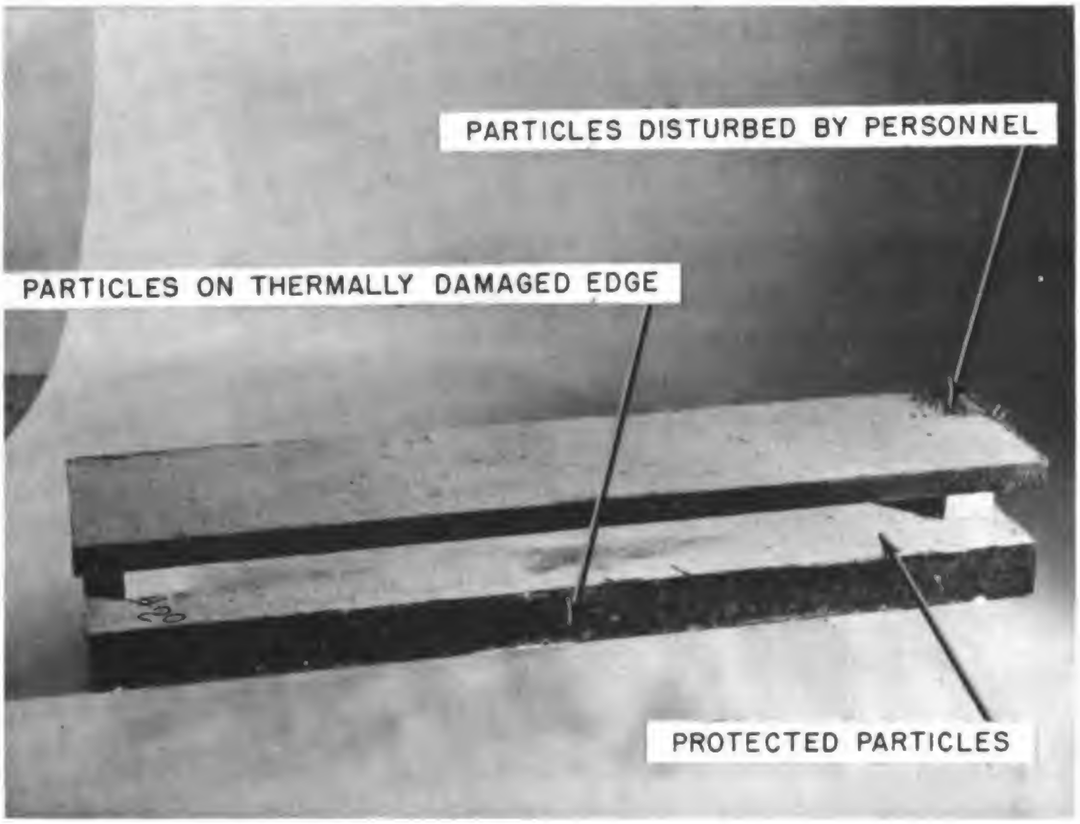



Fig. 4.5—Typical life-float section.

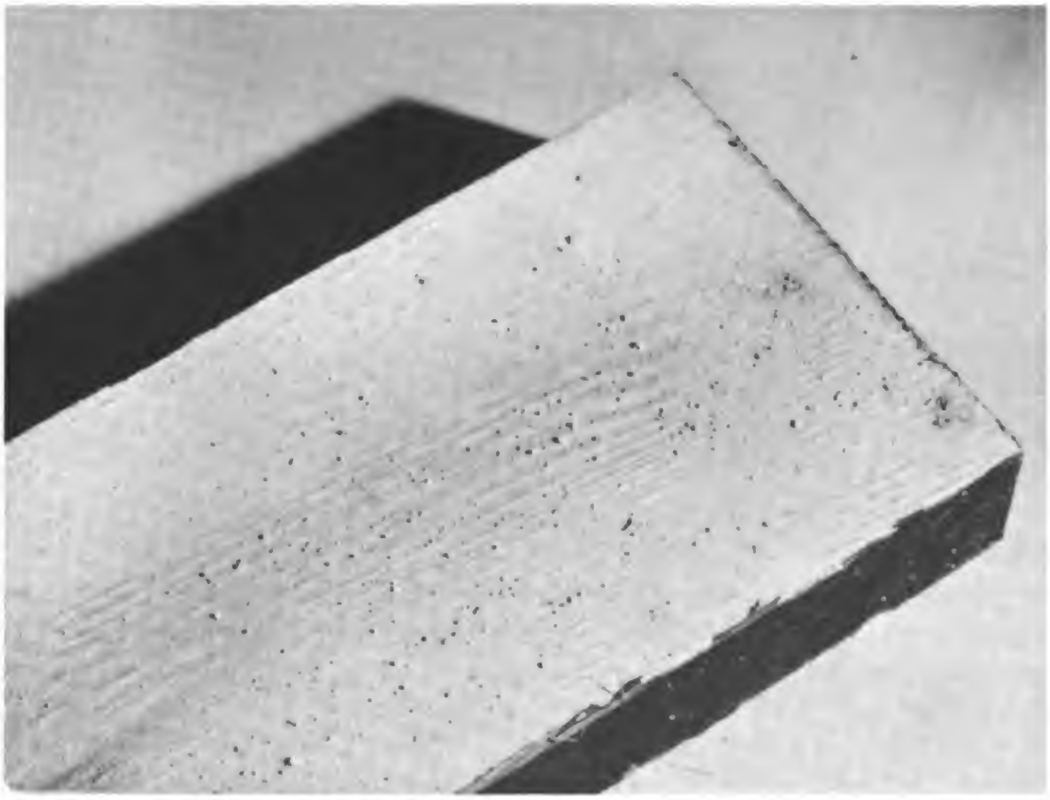


Fig. 4.6—Particle deposition on life-float decking (lower deck of Fig. 4.5).

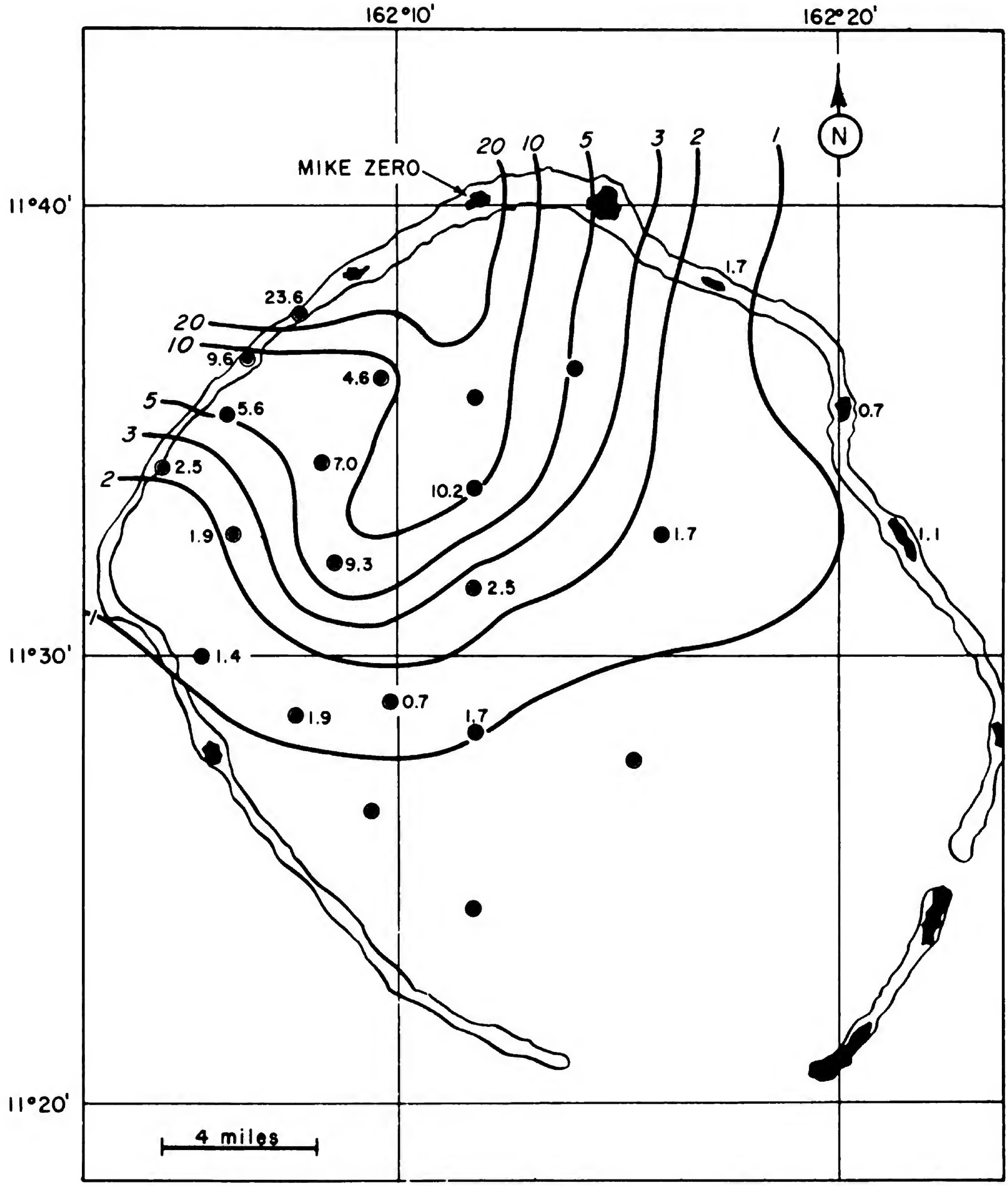



Fig. 4.8—Mass distribution of fall-out (g/sq ft).

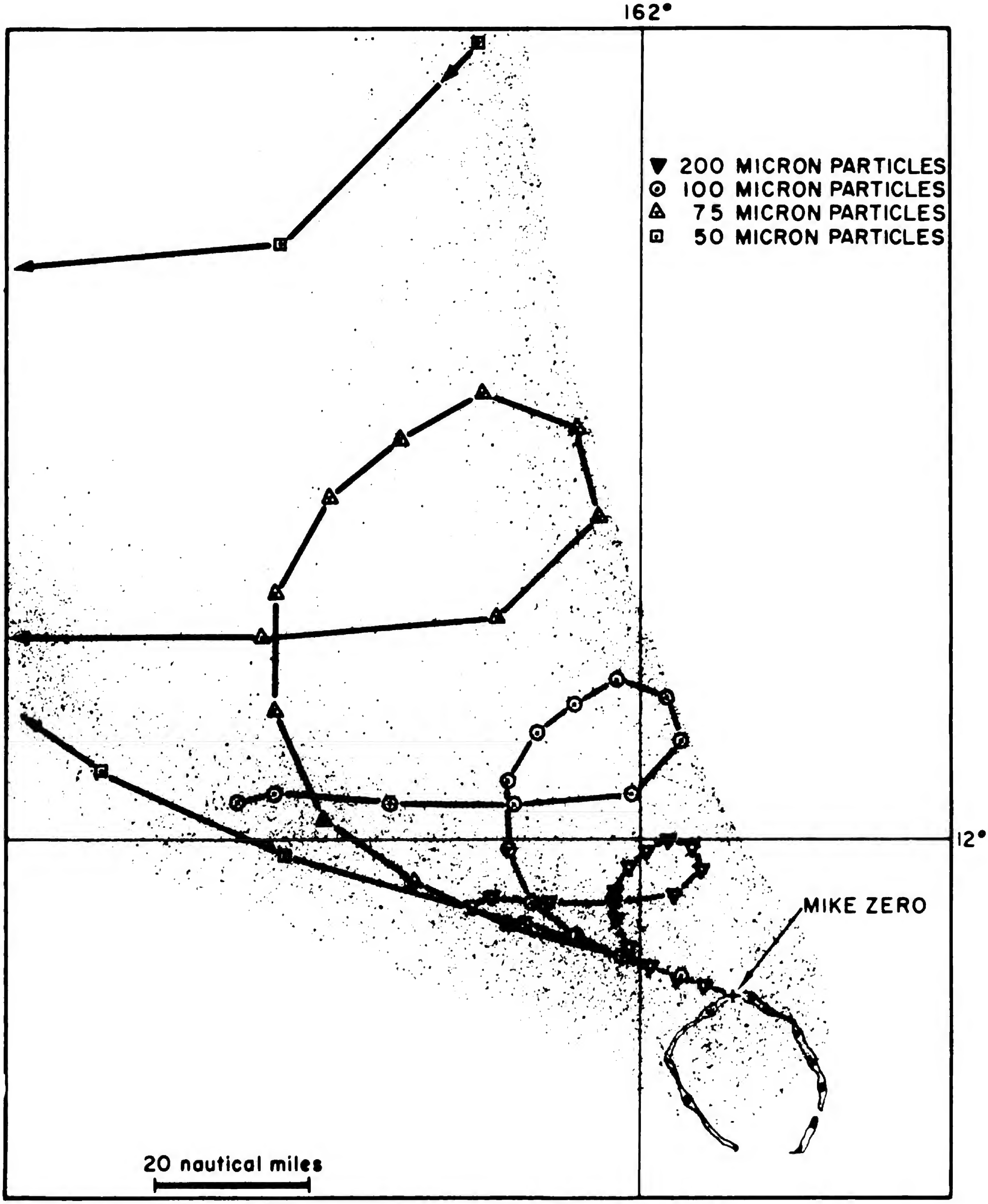



Fig. 6.1—Predicted area of primary fall-out.

WT-915

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# OPERATION CASTLE

## Project 2.5a

# DISTRIBUTION AND INTENSITY OF FALLOUT

*REPORT TO THE SCIENTIFIC DIRECTOR*

by

R. L. Steton
E. A. Schuert
W. W. Perkins
T. H. Shirasawa
H. K. Chan

This document regraded
From SECRET
To UNCLASSIFIED
Date 14 July 82
Authority DNA LTR 6/14/82

(The Castle-Bravo 15 megaton H-bomb test of 1 March 1954, which contaminated a Japanese tuna trawler and islanders)

January 1956

[redacted]

[redacted]

U. S. Naval Radiological Defense Laboratory
San Francisco 24, California

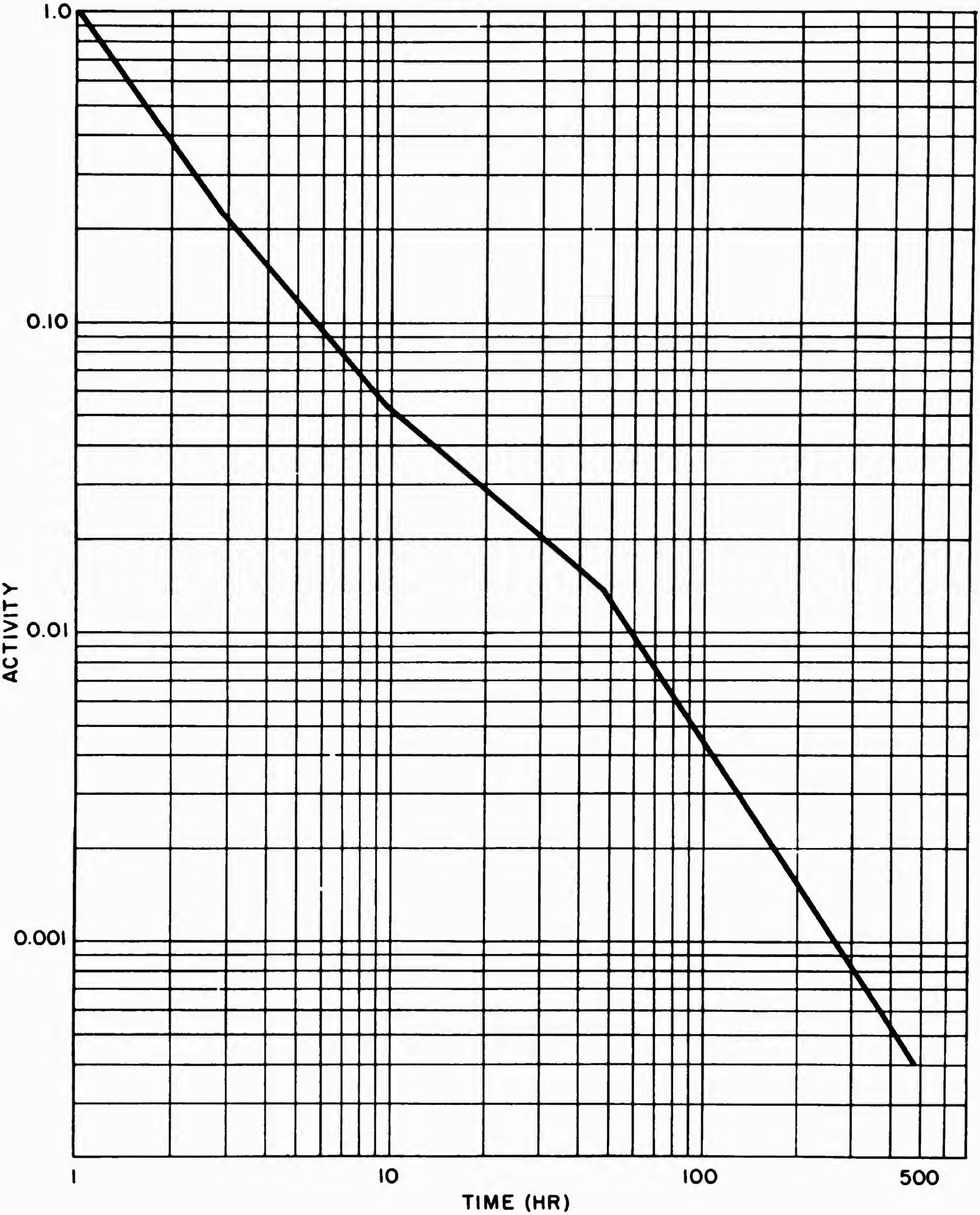


Fig. 5.3 Composite Gamma Ionization Decay Curve

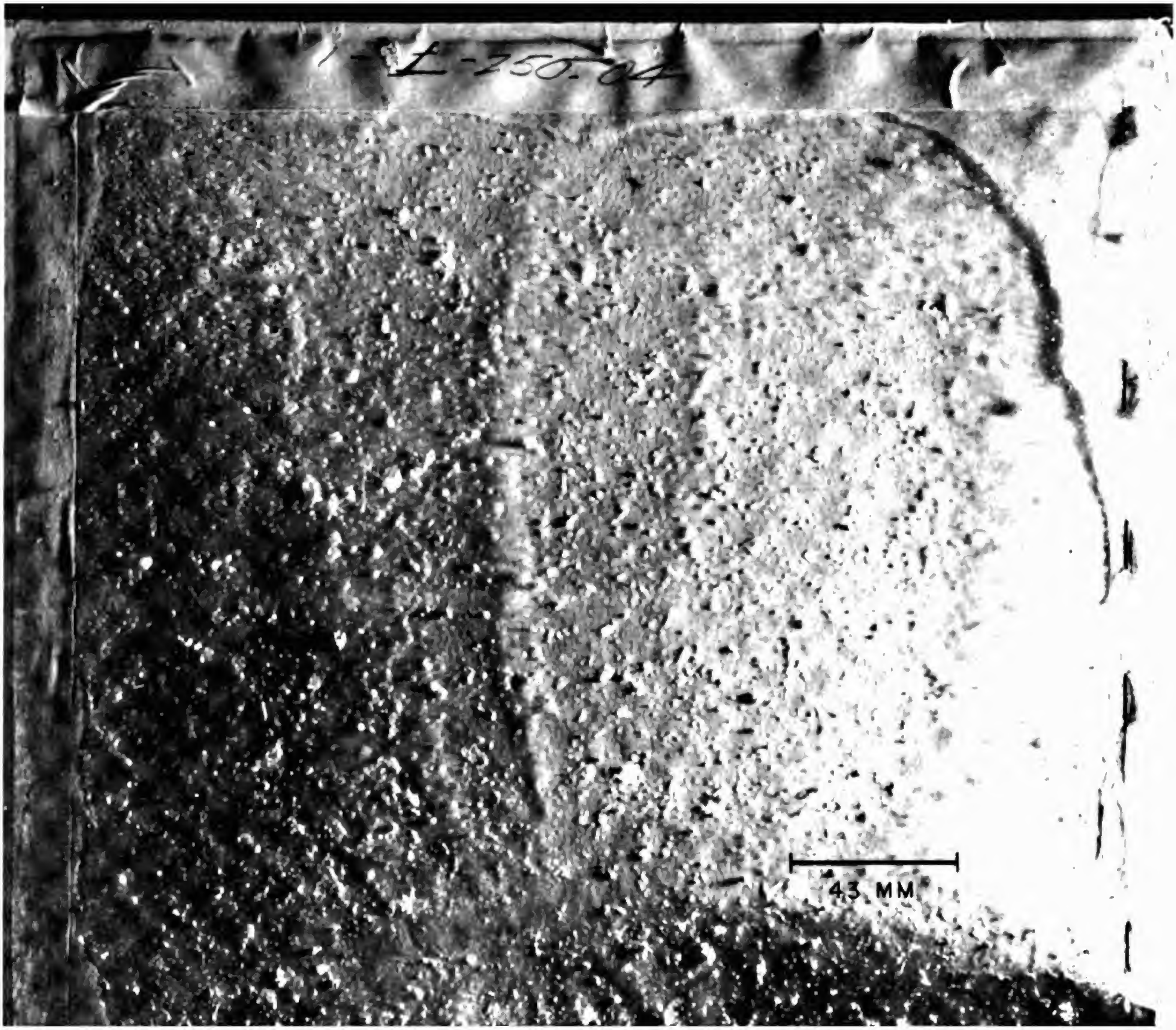


**Fig. 5.10 Shot 1, Fallout Particulate, Station 250.04**

This is a raft downwind in Bikini Lagoon, which received a land equivalent of 113 R/hr (1 hour reference gamma dose rate), according to Figures 2.2 and 6.1. Land equivalent dose rates were 7 times the raft dose rate in the lagoon.

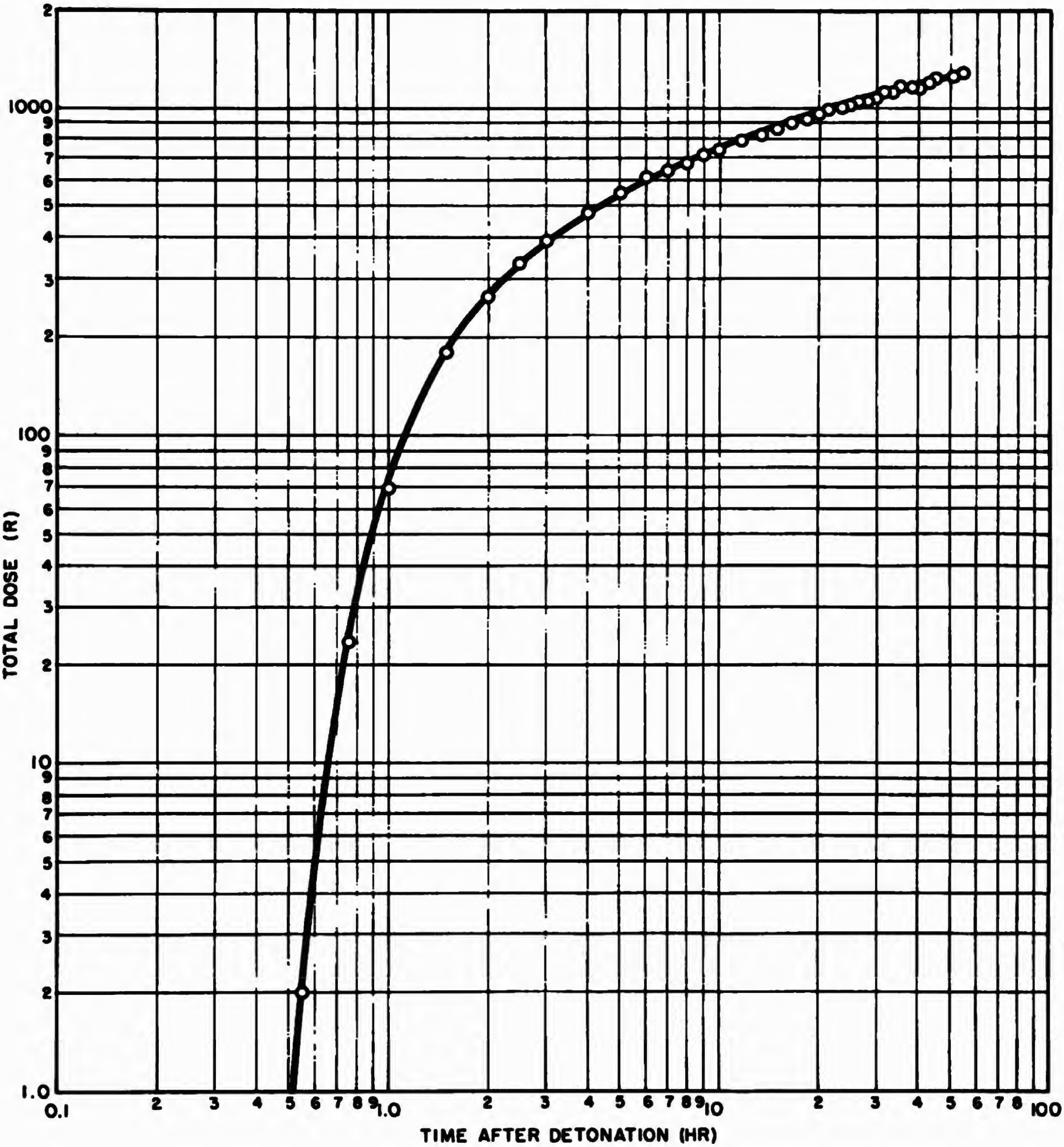


**Fig. 5.11 Shot 1, Integrated Gamma Dose, Station 251.03**

Bikini (How) Island in Bikini Atoll, which received a land equivalent of about 725 R/hr gamma at 1 hour reference time, according to Figures 2.2 and 6.1.

[redacted]

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SANITIZED VERSION

TECHNICAL ANALYSIS REPORT - AFSWP NO. 507-SAN

# RADIOACTIVE FALL-OUT HAZARDS FROM SURFACE BURSTS OF VERY HIGH YIELD NUCLEAR WEAPONS, Sanitized Version

by


D. C. Borg
L. D. Gates
T. A. Gibson, Jr.
R. W. Paine, Jr.

WEAPONS EFFECTS DIVISION


This Armed Forces Special Weapons Project Technical Analysis Report is a staff study prepared for the Chief, AFSWP on a subject of military interest. The conclusions may be modified as new data become available.




MAY 1954

HEADQUARTERS, ARMED FORCES SPECIAL WEAPONS PROJECT
WASHINGTON 13, D. C.


[redacted]

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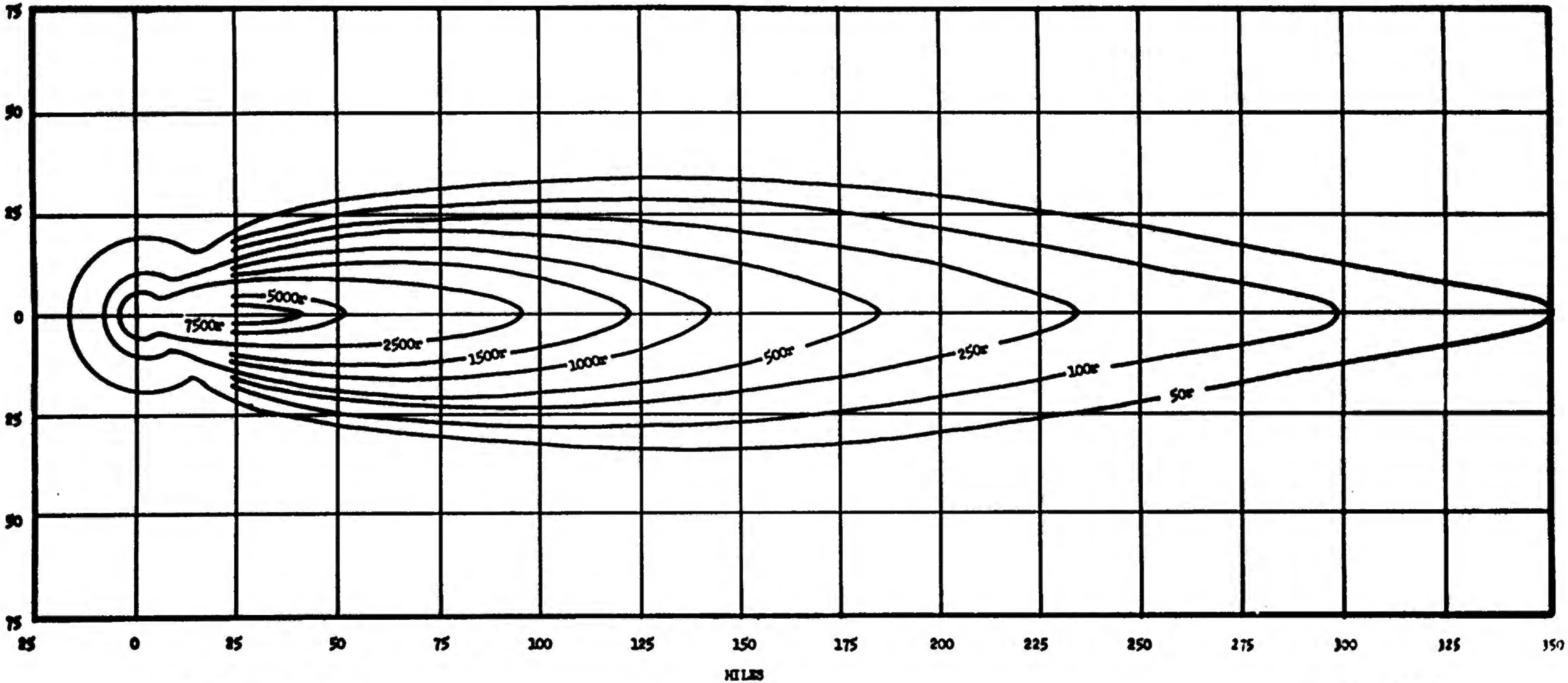
Fig. A TOTAL DOSE FROM TIME OF FALL OUT TO H+50

Idealized Fall-out Contours for a 15 MT Land-surface Burst with a 15 Knot Effective Wind

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The shielding afforded by an ordinary frame house may effectively reduce the size of the hazard areas by a factor of about two, and a basement shelter by a factor of ten or more. Virtually complete protection against the lethal effects of radioactive fall-out can be obtained if personnel have protection equal to or better than that afforded by a simple underground shelter with at least three feet of earth cover, and if they are evacuated after a week or ten days in such a shelter.

One may draw the following conclusions from this analysis:

a. Very large areas, of the order of 5,000 square miles or more, are likely to be contaminated by the detonation of a 15 megaton yield weapon on land surface, in such intensities as to be hazardous to human life.

b. The fact that a large percentage of the radiologically hazardous area will lie outside the range of destructive bomb effects for normal wind conditions, extending up to several hundred miles downwind, makes the radiological fall-out hazard a primary anti-personnel effect.

c. Accurate pre-shot prediction of the location of the hazardous area with respect to the burst point is virtually impossible without extensive wind data at altitudes up to about 100,000 feet, owing to the sensitive wind-dependence of the distribution mechanism.

d. The fall-out contaminant can be expected to decay at such a rate that all but the most highly contaminated areas could be occupied by previously unexposed personnel on a calculated risk

basis within a few days after the contaminating event; and even these highly contaminated areas may then be entered briefly by decontamination teams.

e. Passive defense measures, intelligently applied, can drastically reduce the lethally hazardous areas. A course of action involving the seeking of optimum shelter, followed by evacuation of the contaminated area after a week or ten days, appears to offer the best chance of survival. At the distant downwind areas, as much as 5 to 10 hours after detonation time may be available to take shelter before fall-out commences.

f. Universal use of a simply constructed deep underground shelter, a subway tunnel, or the sub-basement of a large building could eliminate the lethal hazard due to external radiation from fall-out completely, if followed by evacuation from the area when ambient radiation intensities have decayed to levels which will permit this to be done safely.

g. It is of vital importance for individuals in hazardous areas to seek optimum shelter at once, since the dosage received in the first few hours after fall-out has commenced will exceed that received over the rest of a week spent in the contaminated area.

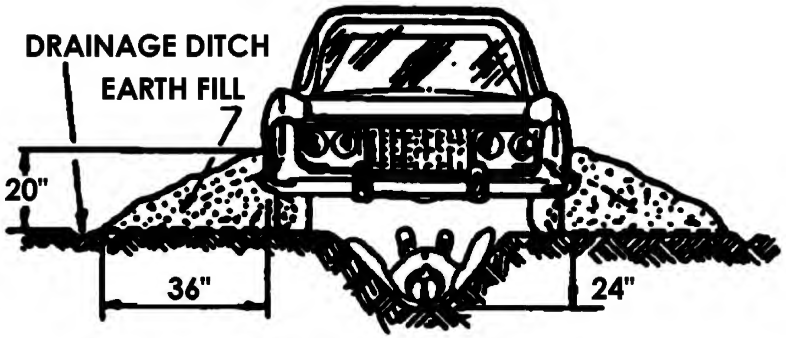
Table II

Total Isodose Contour: 500r from Fall-out to H+50 Hours

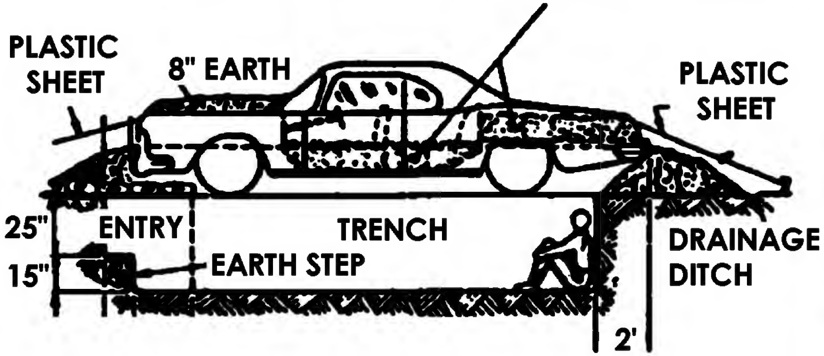
| Yield (MT) | 15 | 1 | 10 | 60 | * 60 |
|---|---|---|---|---|---|
| Downwind extent (mi) | 180 | 52 | 152 | 340 | (307) |
| Crosswind axis (mi) | 40 | 12 | 34 | 70 | |
| GZ circle radius (mi) | 11.5 | 3.85 | 9.7 | 21 | |
| GZ circle displacement (mi) | 3.5 | 1.2 | 3 | 5.75 | |
| Area ($mi^2$) | 5400 | 470 | 3880 | 17,900 | (16,250) |
| Area of true ellipse ($mi^2$) | (5650) | (491) | (4055) | (18,700) | |

* Using Part D, Chapter II.

# CAR-OVER-TRENCH FALLOUT SHELTER (EXPEDIENT SHELTER HANDBOOK)



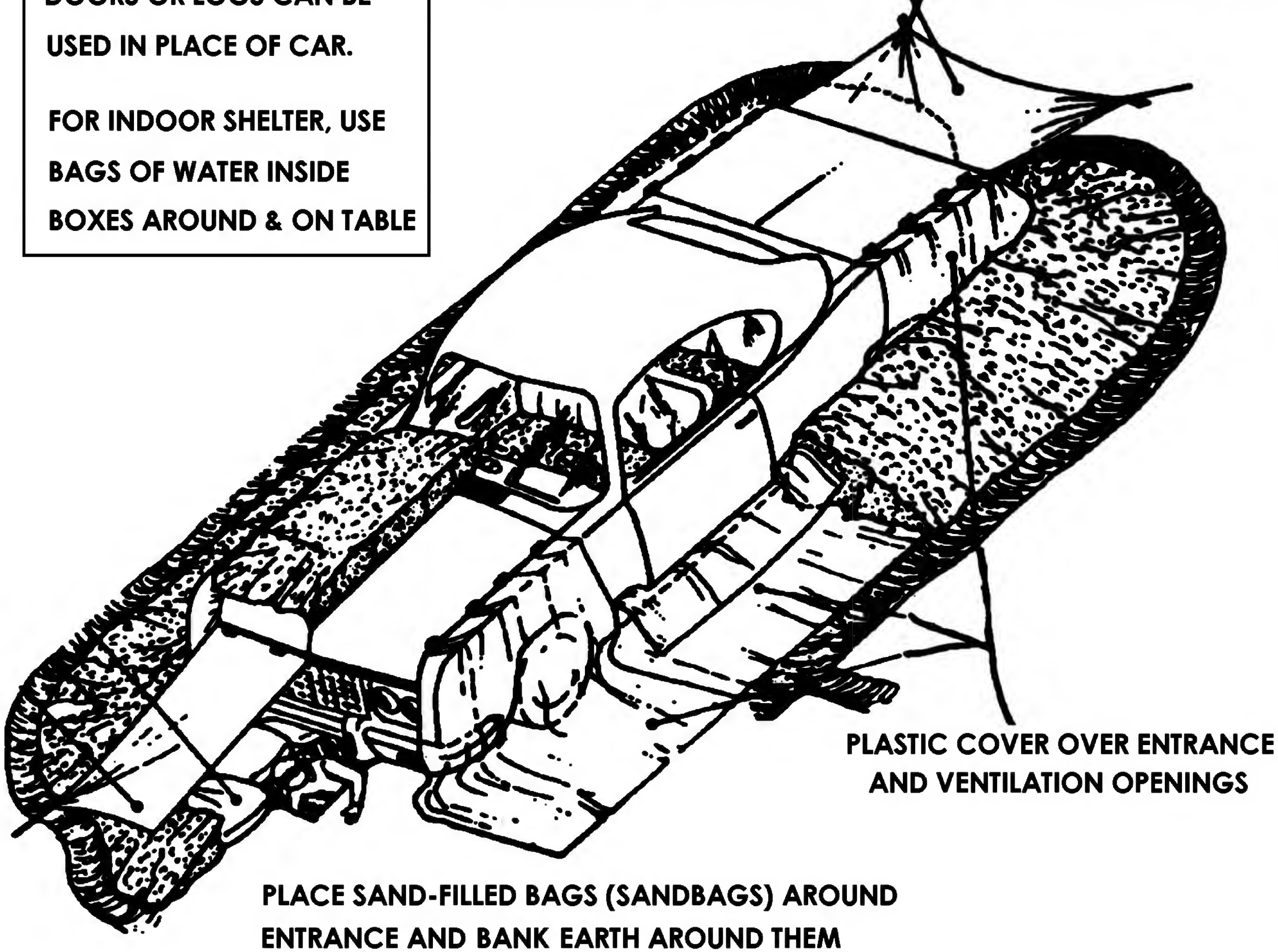

COVER FLOOR AND TRUNK WITH PLASTIC SHEET
PLACE 1 FOOT OF EARTH ON FLOOR AND TRUNK




BANK EXCAVATED EARTH 20 INCHES HIGH AROUND CAR
PLACE 8" OF EARTH ON CAR HOOD
DIG SHALLOW DRAINAGE DITCH AROUND FILL

DOORS OR LOGS CAN BE USED IN PLACE OF CAR.

FOR INDOOR SHELTER, USE BAGS OF WATER INSIDE BOXES AROUND & ON TABLE



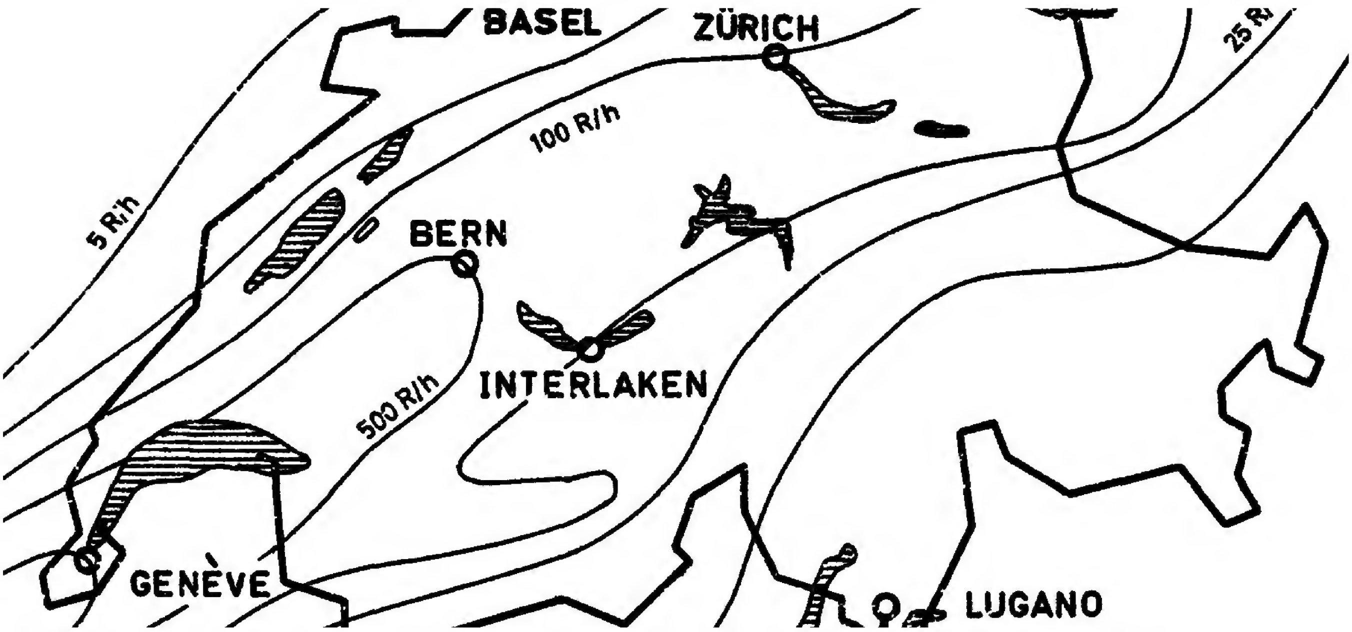

PLACE SAND-FILLED BAGS (SANDBAGS) AROUND ENTRANCE AND BANK EARTH AROUND THEM

# FACHVERBAND FÜR STRAHLENSCHUTZ E.V.

Mitgliedsgesellschaft der International Radiation Protection Association (IRPA)

# PROCEEDINGS of a SYMPOSIUM

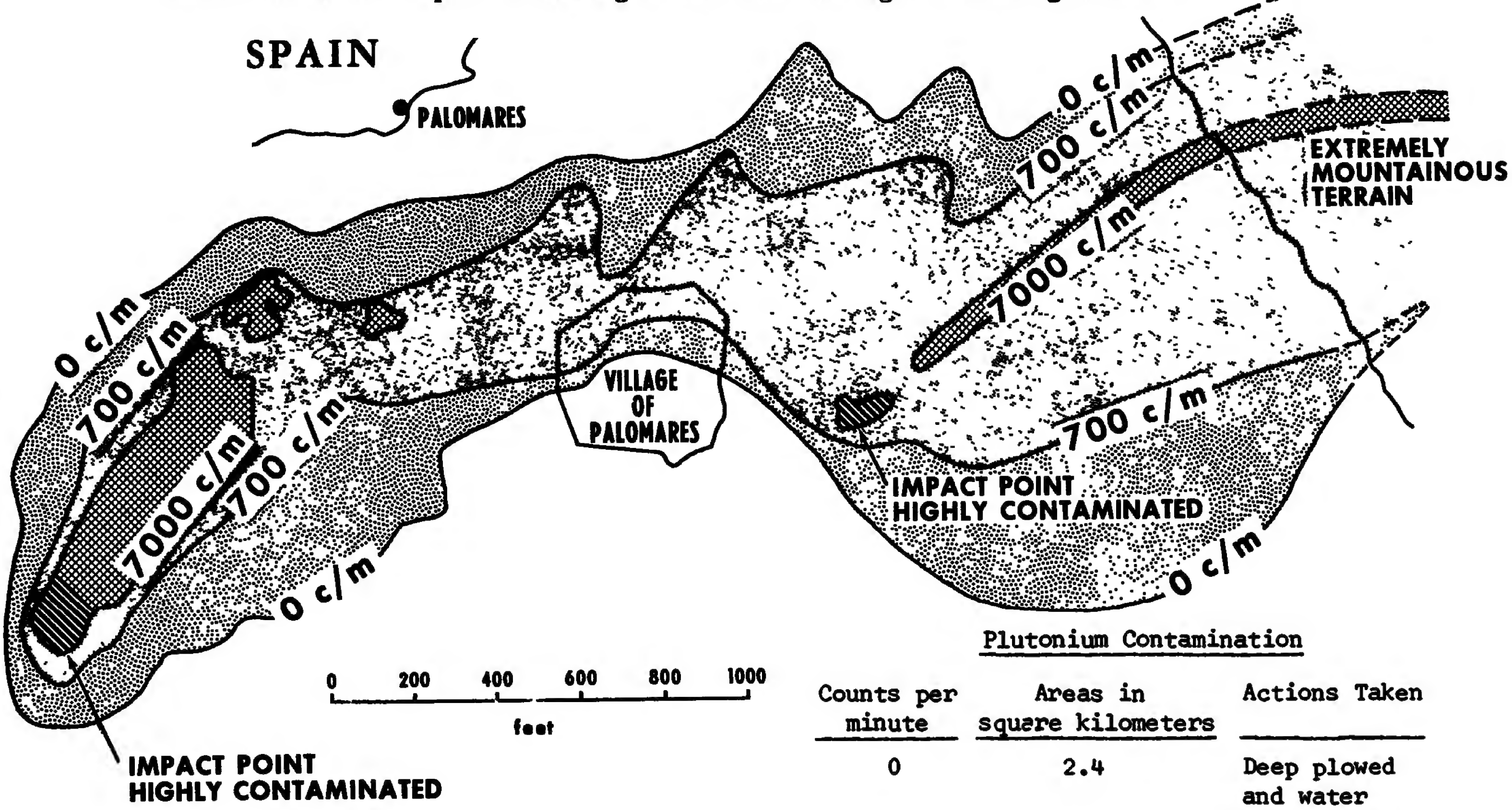
## RADIOLOGICAL PROTECTION OF THE PUBLIC IN A NUCLEAR MASS DISASTER




Front row: O. Burkhardt, Administrative Secr. of the Symposium - S. Prêtre, Pres. of "Fachverband für Strahlenschutz" - Dr. C.F. Miller, URS Corp., Burlingame, California - Bundesrat L. von Moos, Member of the Swiss Government, Minister of Justice and Police - W. König, Dir. of the Swiss Federal Office of Civil Defense - Prof. E.P. Wigner, Princeton Univ., Nobel Prize in Physics 1963 - H. Brunner, Scientific Secr. of the Symposium.

## INTERLAKEN, SWITZERLAND, 26 MAY–1 JUNE 1968

On January 17, 1966, a B-52 U.S. Air Force aircraft with nuclear bombs aboard crashed in Spain following an accident during a refueling mission.




Plutonium Contamination

| Counts per minute | Areas in square kilometers | Actions Taken |
|---|---|---|
| 0 | 2.4 | Deep plowed and water |
| 700 | 2.0 | (Deep plowed, |
| 7,000 | 0.17 | (watered and (vegetation removed |
| over 60,000 | 0.022 | Surface scraped |

**Plutonium quickly oxidizes forming insoluble plutonium oxide.**

**The potential sources of inhalation of plutonium under these conditions are one, the cloud of radioactive material as it rolls by immediately after the event and, two, resuspension of the plutonium from the ground into the air afterwards. Available data indicate that the first source will probably result in a higher amount of plutonium being deposited in the lungs.[1.]**

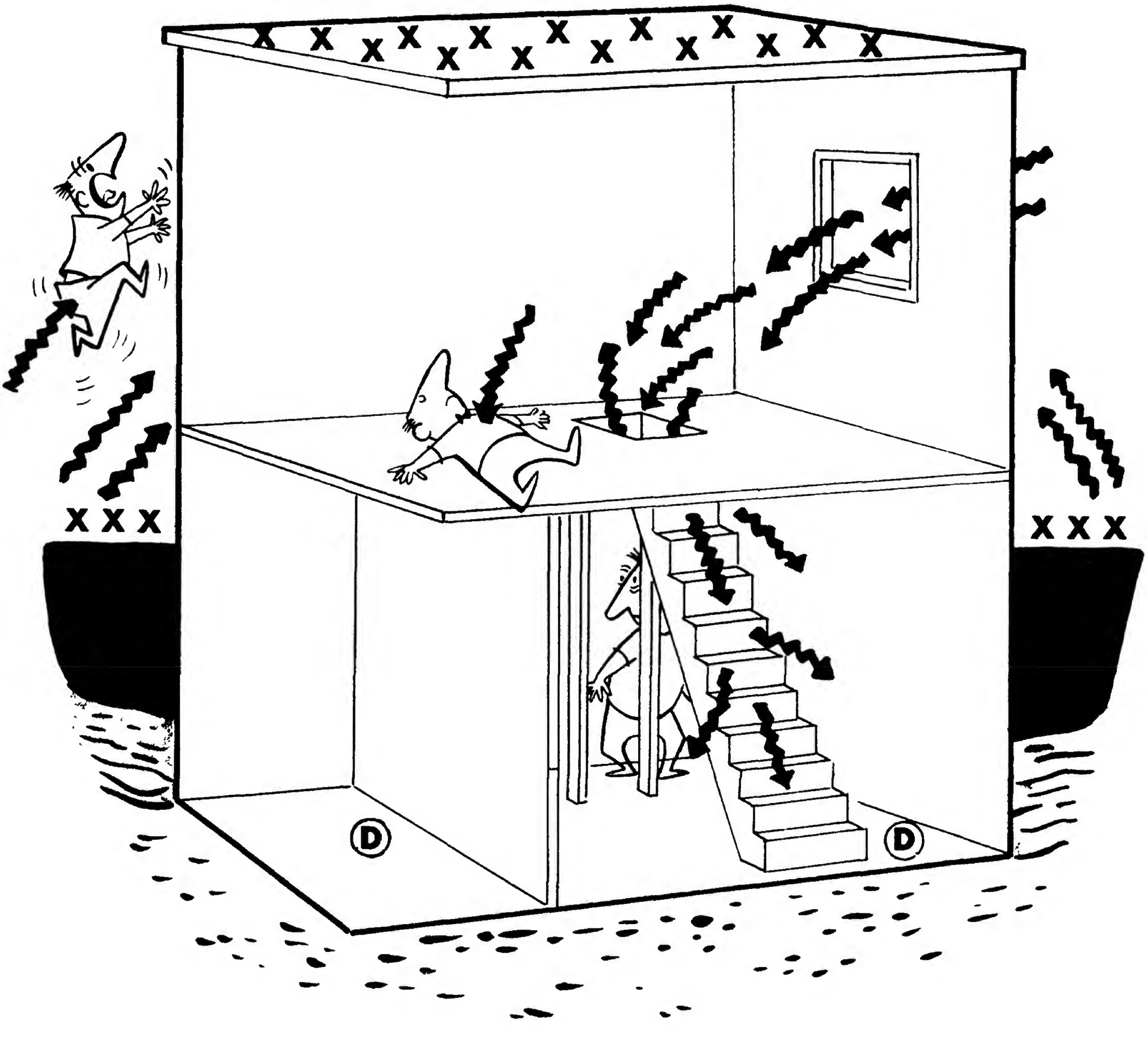
**In short, experiments[1., 2.] showed that if a person were exposed to the highest concentration of plutonium in the cloud from such an accident he might receive a total radiation dose to the lungs of about 5 to 10 rem. The second of the major field tests was conducted under inversion meteorological conditions in order to maximize the concentration in the air at ground level.**

1. Summary Report, Test Group 57; Report No. ITR-515 (Del.), Shreve, J.D., Jr. April 1958.
2. Operation Roller Coaster 1963. "Biological Studies Associated with a Release of Plutonium." Wilson, Robert and Terry, Jack.

STATUS OF FALLOUT SHIELDING CALCULATIONS IN THE USA

C. Eisenhauer, NBS

In summary, there is a continuing program of experimentation going on to check the accuracy of the present calculations used to predict protection from fallout. However, this program must be accompanied by another which studies the impact of inaccuracies on the various phases of the Civil Defense program. It is not unlikely that there is a range of protection factors for which much greater accuracy is required.



# THE NATURE AND BEHAVIOR OF LOCAL FALLOUT

By

Carl F. Miller

## THE FORMATION PROCESS

The larger glassy particles, formed from vaporized and melted soil material, are entrained in the fireball before it cools to the melting point of the soil. During this time, the larger melted particles not only collide and coalesce with the smaller liquid soil droplets, but serve as a condensation media for other vaporized condensable fission products. The crystalline particles, entering the fireball after it has cooled to temperatures less than the melting point of the soil material, collect only late-condensing fission product radionuclides on their surfaces in addition to intercepting a few of the small vapor-condensed particles. The late-condensing fission products consist mainly of the volatile elements such as Sb, Te, and I, and the daughter products of rare gases such as Rb and Cs.

The derived specific activity of the local fallout from Shot SMALL BOY, a low-yield device detonated near ground surface at the Nevada Test Site, is shown as a function of particle diameter in Figure 1. The low values of the specific activity for the smaller particles resulted from the unavoidable presence of extraneous local dust particles in the collected samples.

The curve of Figure 1 may be represented by:

$$C = \frac{3.5 \times 10^{18} \left[1 - e^{-6.9 \times 10^{-4} d}\right]}{d}, \quad d = 50 \text{ to } 4{,}000 \text{ microns} \qquad (1)$$

where d is the particle diameter in microns and C is in fissions per gram. The range in d indicates that essentially all of the radioactive particles falling in the local fallout area were greater than 50 microns and that essentially none were found larger than 4,000 microns. The form of Equation 1 and the numerical coefficient values indicate that the gross radionuclide content of the particles is essentially proportional to particle volume or weight for particles with diameters between about 50 and 200 microns. For particles with larger diameters, the radionuclide content becomes increasingly concentrated on the surface of the particles and at diameters of about 2000 microns and larger, the radionuclide content is essentially proportional to

surface area (i.e., to 1/d). The specific activity of the smaller particles would be expected to be larger than the limiting value of Equation 1 and should increase somewhat as the diameter decreases below about 50 microns.

The major significance of the two-stage fallout formation process, aside from the resulting bimodal particle type composition, is that the radionuclides that condense into the liquid droplets in the first stage become immobilized with regard to latter contamination of water and cycling in food chains; but the radionuclides that condense in the second stage on the surfaces of the particles may not be permanently immobilized and do become involved in later biochemical processes.

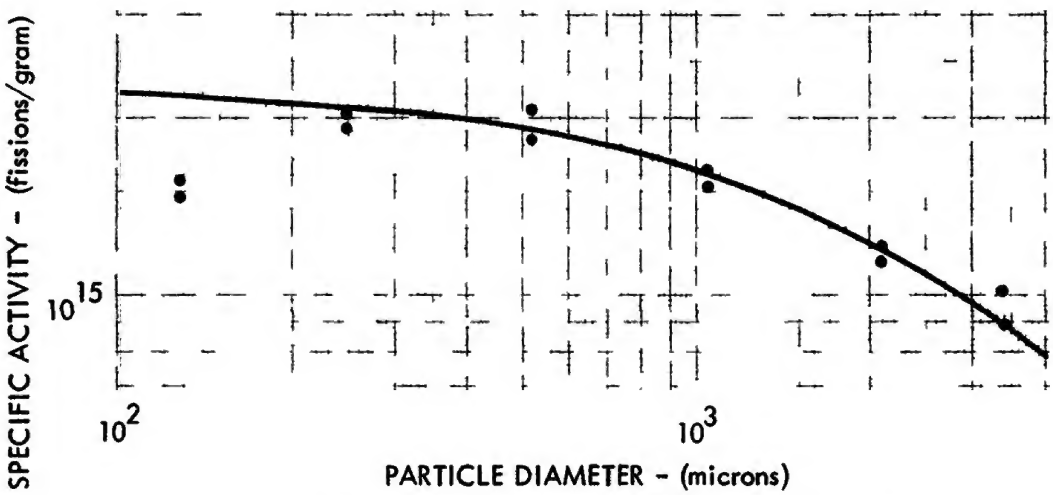


Figure 1. Specific Activity For Shot Small Boy.

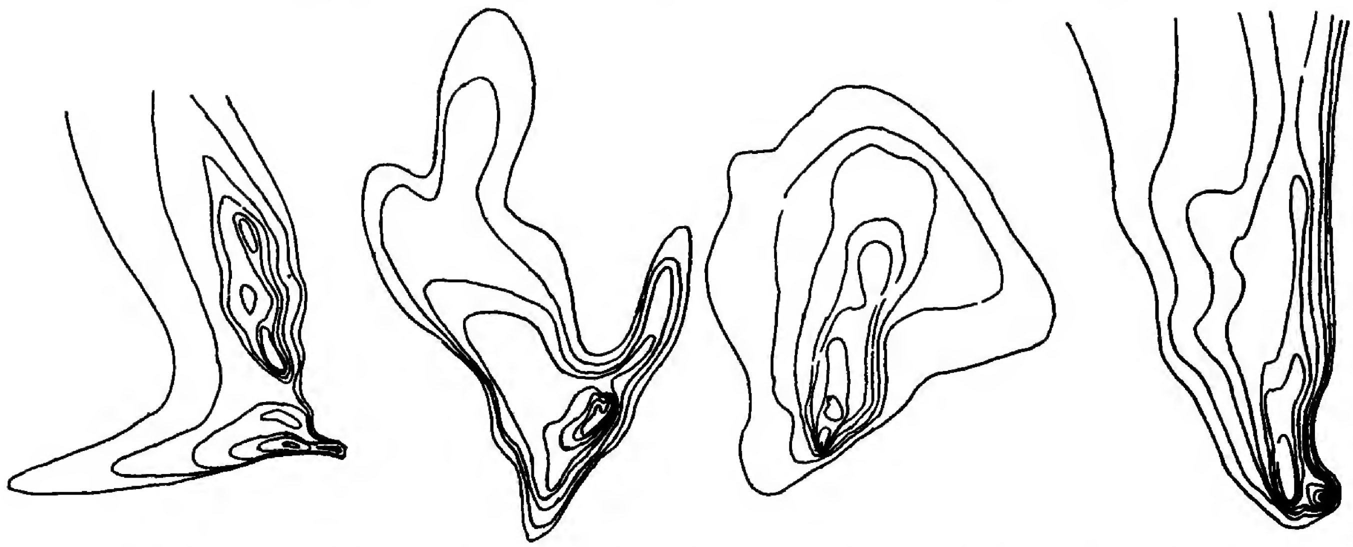


Figure 2. Example Representations of Observed Fallout Patterns.

As the fireball cools and rises into the atmosphere, toroidal circulations take place. This circulation apparently concentrates the remaining gaseous radionuclides and smaller particles in the center of the toroid and, due to the downward flow of air at the periphery, accelerates the falling out of the larger particles. Thus, the time of arrival of the largest fallout particles is usually less than is estimated on the basis of free fall from the bottom of the cloud.

# BETA RADIATION HAZARDS AND BETA-GAMMA RELATIONSHIPS ASSOCIATED WITH LOCAL FALLOUT

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Four cases of beta-ray burns of the hands, which occurred during an atomic bomb test at Eniwetok, have been reported by Knowlton et.al.[2] Two of the men received beta ray doses of 5,000 - 10,000 rads, another received 8,000 - 16,000 rads, and the fourth received 3,000 - 4,500 rads. For all but the smallest dose, skin damage was so extensive that grafts were required. There was loss of mobility of some of the fingers. In one case serious ulcers persisted for periods greater than 100 days after the exposure. The effects of the smallest dose were less pronounced; however, the damage persisted for a period greater than 50 days.

Amount of Transepidermal Radiation Required for the Production of Recognizable Transepidermal Injury (Porcine Skin) From Ref. (1)

| Isotope | Maximum Beta Energy (Mev) | Surface Dose Required (rep) | Estimated Dose at 0.09-mm Depth (rep) |
|---|---|---|---|
| S-35 | 0.17 | 20,000 | 1200 |
| Y-91 | 1.53 | 1,500 | 1200 |

| | |
|---|---|
| 2000-4000 rad | Early erythema under 24 hours<br>Skin breakdown in 2 weeks |
| 4000-10,000 rad | Severe erythema in 24 hours<br>Severe skin breakdown in 1-2 weeks |
| 10,000-30,000 rad | Severe erythema in 4 hours<br>Severe skin breakdown in 1-2 weeks |
| 30,000-100,000 rad | Immediate skin blistering (less than 1 day) |

The expected beta dose rate at contact in a large field contaminated by fallout was calculated[10] to be 40 times the gamma exposure-rate reading taken at 3 feet. For example if the gamma reading at 3 feet is 100 R/hr, the expected beta dose rate at contact will be 4,000 rads/hr. This is true for a beta-particle to gamma-photon ratio of 1. This ratio is approximately equal to unity for times after a nuclear burst of a few hours to 3 or 4 months. At early times (a few minutes to an hour) the ratio may be as high as 2, in which case the beta dose rate will be 80 times the gamma exposure rate.

The beta doses associated with local fallout contamination of terrain and clothing have also been estimated by Pretre[11] who compared the beta and gamma doses to people exposed to terrain and clothing contaminated with fallout. His calculations were essentially in agreement with those reported in reference 10.

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2. Knowlton, N.P., Leifer, E., Hogness, J.R., Hempelmann, L.H., Blaney, L.F., Gill, D.C., Oakes, W.R., and Shafer, C.C., "Beta Ray Burns of Human Skin", J.A.M.A., 141, 239, 1949.

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11. Pretre, S., "Importance Biologique Relative des Doses Beta de la Peau Comparees aux Doses Gamma du Corps Entier", Section ABC 33/22 Bulletin ABC No. 7, April 1965.

http://www.osti.go OSTI Identifier: 4822127 Report CONF-680507 (31 October 1969): Radiological Protection of the Public in a Nuclear Mass Disaster, Symposium, Interlaken, Switzerland, 26 May-1 June 1968

# BASIC CHARACTERISTICS OF NUCLEAR RADIATION FROM FALLOUT

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Radioactivity may also be produced by neutron interactions within the weapon itself. In many weapons the primary radiation of this type is $^{239}Np$ (half-life, 2.3 days) produced by the reaction $^{238}U(n,\gamma)$ $^{239}U(\beta)$ $^{239}Np$ because of the presence of $^{238}U$ (see pp. 1690-91 of reference 17). The nuclide $^{239}U$ decays with a half-life of only 23.5 minutes so usually is not observed in significant amounts in fallout measurements.

Other materials besides uranium can be introduced into the regions surrounding the active portions of a nuclear weapon. These materials are then subjected to a tremendous neutron flux density when the weapon is detonated, with the result that many radioactive nuclei are formed. At one time the hazards produced by gamma radiations of a so-called cobalt bomb were discussed extensively. Based on what he considered reasonable assumptions, Dunning[18] calculated the residual-radiation exposure and exposure rate that one could expect from a one megaton nuclear weapon, containing cobalt, that derived half of its energy from fission and half from fusion. His conclusions are that the effect of the cobalt is almost insignificant at very early times but it becomes appreciable after several days. For example, his calculations indicate that one hour after detonation the gamma-ray exposure rate produced by the fission products is about $5.9 \times 10^5$ times the exposure rate produced by the $^{60}Co$ gamma rays, but after 30 days the fission-product exposure rate is only 0.02 times the $^{60}Co$ exposure rate. An infinite time extrapolation shows the contribution to the total-exposure by fission-product radiations and by $^{60}Co$ radiations to be approximately equal.

## Comparison of Fallout and Fission Product Gamma-Ray Spectra

Cook[19] has compared calculations by Nelms and Cooper[15] of expected gamma-radiation spectra from radioactive fission-product nuclides with measured gamma-ray spectra of fallout samples. These comparisons indicate that there is a reasonably close resemblance between calculation and experiment for photons with energies greater than 290 keV. However, the $^{239}Np$ radiations in the experimental measurements usually completely obliterate the fission-product radiations in the energy regions between 100 and 290 keV.

(Np-239 and U-237 (in thermonuclear bombs) emit easily shielded soft ~ 0.1 MeV gamma rays.)

Experiments Using Real Fallout Fields

Mather et al.,[56] Huddleston et al.,[57] and Frank[58] have measured the gamma radiation emitted by fallout that resulted from two near-surface bursts at the Nevada Test Site. All three groups used scintillation spectrometers, with NaI(Tl) detectors, to measure pulse height distributions.

The effect of ground roughness has been determined in these experiments by measurements of the direct component of the radiation.

In both cases the effect of ground roughness could be simulated by assuming a plane source covered by a layer of earth. In the area where Mather et al. made their measurements, the layer of earth amounted to a thickness of 0.45 $g/cm^2$ plus 106 cm of air, and in the area measured by Frank a thickness of 0.95 $g/cm^2$ plus 122 cm of air.

Huddleston et al. compared their dose vs. angle of incidence measurements with a calculation by Spencer[44] to determine the effects of ground roughness. They found angular distributions from measurements made three feet above the surface which, when compared with calculations made by Spencer, are comparable to the radiation expected in air about 40 feet above a planar infinitesimally thin source. Further, they found the distribution over a dry-lake bed to closely approximate Spencer's calculated distribution for an air-equivalent distance of 20 feet, and over a plowed field an air-equivalent distance of between 40 and 60 feet.

The equivalent air thickness reported by Huddleston et al. is somewhat greater (if converted to $g/cm^2$) than the equivalent earth thicknesses reported by Mather et al. and by Frank. The differences may have real significance or they may possibly depend on assumptions made in the calculations. The general conclusions derived from these results are that the use of an equivalent air attenuation to represent the soil attenuation produced by ground roughness effects appears to give results that are in reasonably good agreement with experimental observations.

17. Congress of the U. S., Special Subcommittee on Radiation, "The Nature of Radioactive Fallout and Its Effect on Man." U. S. Government Printing Office, Washington, D. C., 1957.

18. G. M. Dunning, Health Phys. 4, 52-54 (1960).

19. C. S. Cook, Health Phys. 4, 42-51 (1960).

15. A. T. Nelms and J. W. Cooper, Health Phys. 1, 427-441 (1959).

56. R. L. Mather, R. F. Johnson, and F. M. Tomnovec, Health Phys. 8, 245-260 (1962).

57. C. M. Huddleston, Q. G. Klingler, and R. M. Kinkaid, Health Phys. 11, 537-548 (1965).

58. A. L. Frank, Health Phys. 12, 1715-1731 (1966).

44. L. V. Spencer. Structure Shielding Against Fallout Radiation from Nuclear Weapons. Nat. Bur. Std. Monograph 42 (1962).

# THE NATURE OF RADIOACTIVE FALL-OUT AND ITS EFFECTS ON MAN

# HEARINGS

BEFORE THE

## SPECIAL SUBCOMMITTEE ON RADIATION

OF THE

## JOINT COMMITTEE ON ATOMIC ENERGY
## CONGRESS OF THE UNITED STATES

EIGHTY-FIFTH CONGRESS

FIRST SESSION

ON

THE NATURE OF RADIOACTIVE FALLOUT AND ITS EFFECTS ON MAN

MAY 27, 28, 29, AND JUNE 3, 1957

**PART 1**

Printed for the use of the Joint Committee on Atomic Energy

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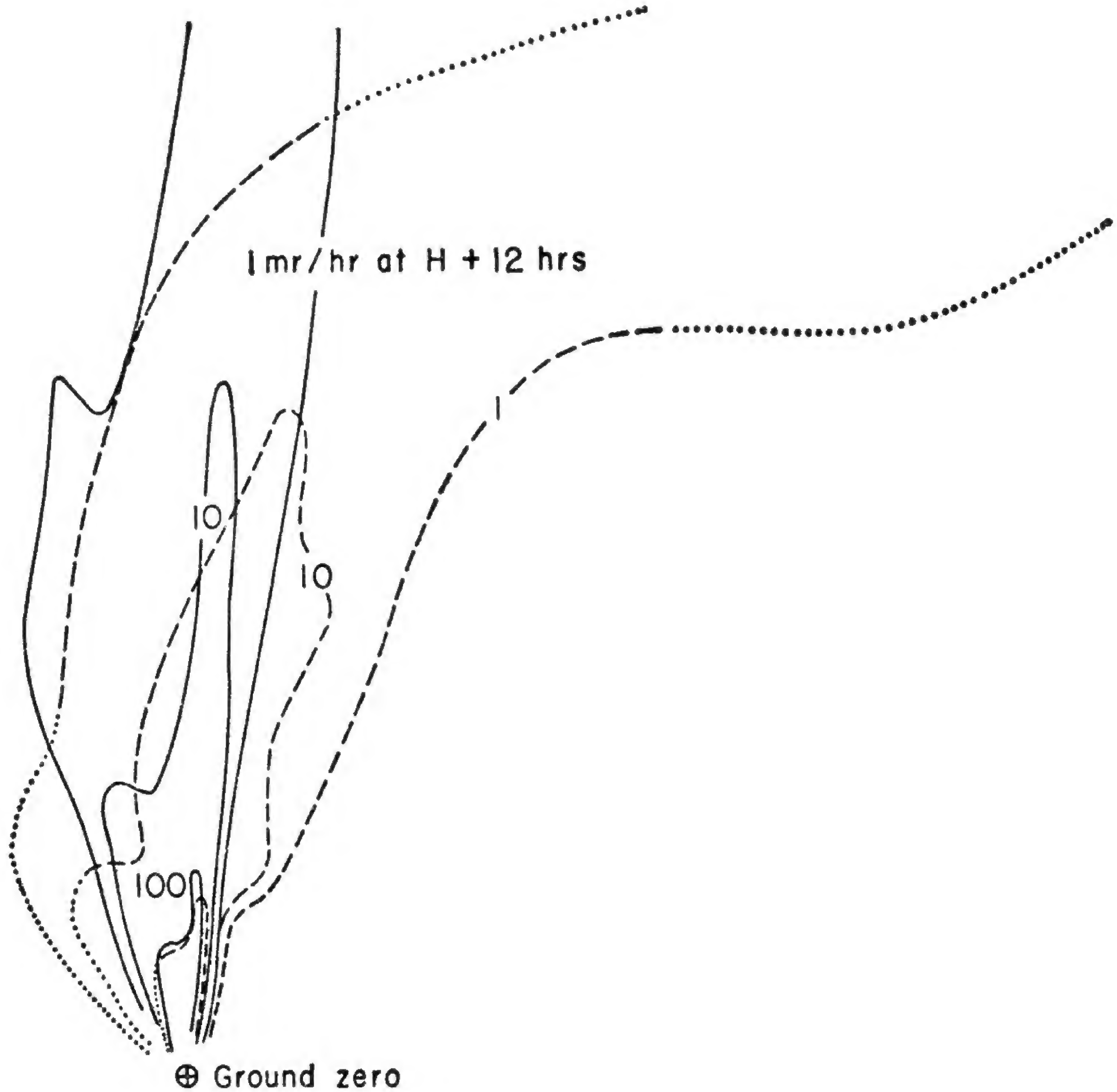


FIGURE 4.—The observed fallout distribution (dashed lines) and the pattern computed by the Weather Bureau using winds predicted at H–2 hours. May 5, 1955.

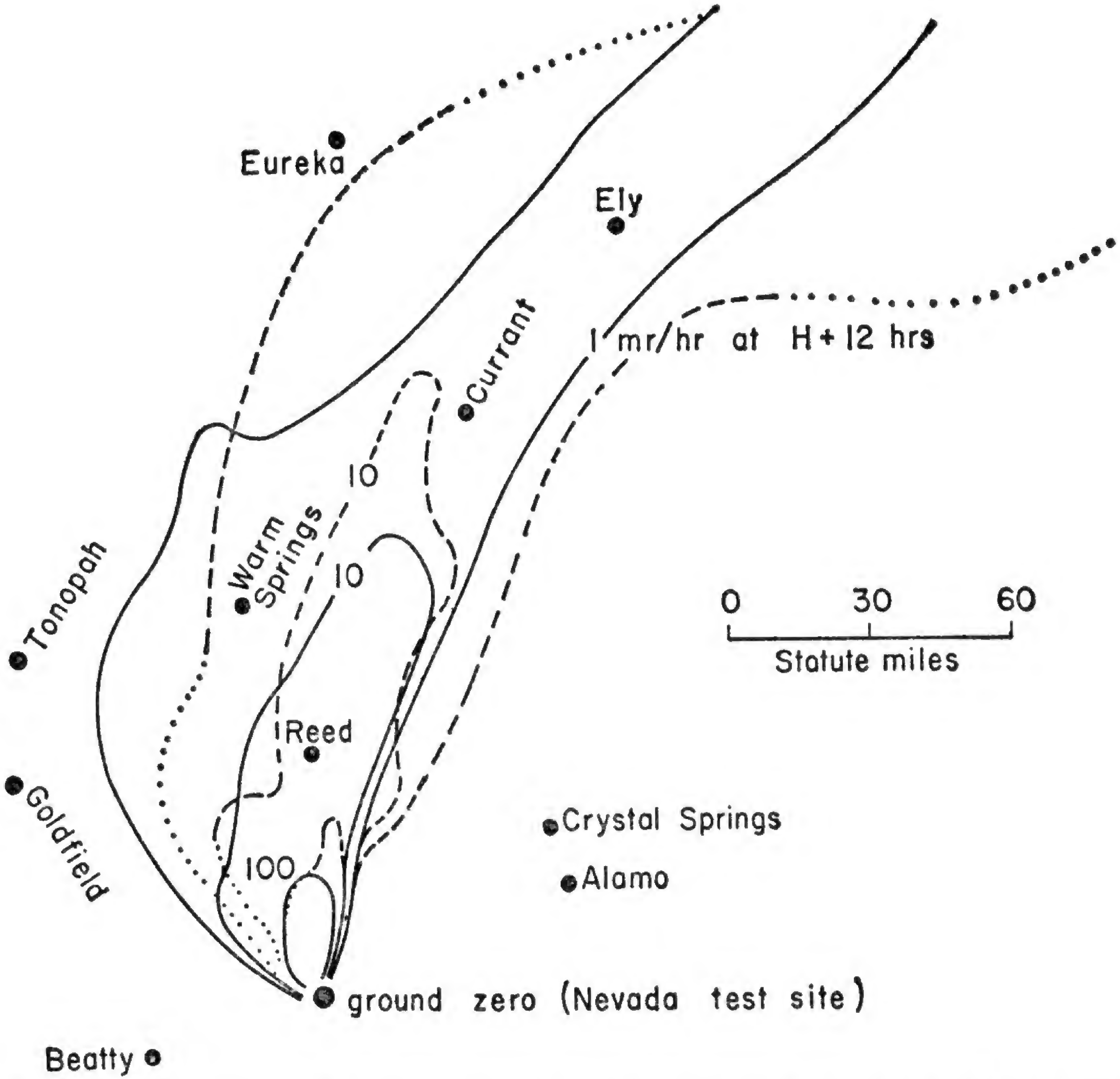


FIGURE 6.—The observed fallout distribution (dashed lines) and the pattern reconstructed by the Weather Bureau using a hand computation with time and space variation of winds (solid lines). May 5, 1955.

MYRON B. HAWKINS (b. 1920), USNR.DL.:

~~tion.~~[1 2 3 4] The contaminability of targets as related to micrometeorology and geometry have not been studied directly, but some information has been derived from experiments with other objectives.[5] As an example, a ship was exposed to fallout from a deep-water detonation.[6 7] The fallout arrived in a 15- to 20-knot wind on the starboard beam.

The following results were obtained:

(*a*) The contamination level (240 readings) on horizontal surfaces varied from 16 percent to 400 percent of the average, i. e., the largest was 25 times higher than the lowest.

(*b*) The gamma radiation level at 3 feet above the deck varied by a factor of 10.

(*c*) The average contamination level for vertical surfaces varied from the average horizontal reading as follows:

1. Forward part of the ship: 40 percent of horizontal average.
2. Aft part of the ship: 20 percent of horizontal average.
3. Lee side: 10 percent of horizontal average.
4. Windward side: approximately equal to horizontal average.

(*d*) Test panels at the stern of the ship had an average contamination level on vertical surfaces three times higher than levels on horizontal surfaces.[8]

Such data cannot be extrapolated or used for predictions without a better understanding of all of the factors involved.

In another example, small buildings and panels of typical building materials were exposed to fallout from land detonations.[4] The contamination levels on typical roofing materials was as much as 300 times higher than that on typical wall panels; or a vertical to horizontal relationship of about 0.3 percent. For panels of the same material, vertical readings were about 10 percent of the horizontal.

The two examples indicate considerable difference in the vertical to horizontal relationships. The characteristics of the fallout appear to have had a considerable influence on this distribution. For instance, the land detonation normally produces a "dry" fallout composed primarily of material from the crater. One can expect masses of 3 to 300 grams of material per square foot to be associated with significant radiation levels at early times. The fallout being a dry powder has little tendency to stick on vertical surfaces.

The fallout from deep-water detonations is largely composed of sea water salts. However, much of the water may evaporate, leaving particles that are damp, semicrystalline masses of a sticky nature. They are capable of sticking to vertical surfaces.

As indicated very little is known of the overall problem of contaminability. It is obvious, however, that two assumptions often made, i. e., ((1) that the fallout is distributed homogeneously on a uniform infinite plane, and (2) that vertical surfaces are not appreciably contaminated) are subject to serious limitations. The ability of a tactical force and/or a civilian population to exploit the variability of the fallout pattern depends upon knowledge we do not have on contaminability.

The contaminability of personnel exposed to the fallout event or working and living in contaminated environments is largely unknown. A study[9] indicating the significance of beta contact hazard to personnel and a requirement for the mass decontamination of personnel, emphasizes the need for additional contaminability information.

---

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[3] Lane, W. B., R. K. Fuller, L. Graham, W. E. Shelberg, Laboratory Studies of the Decontamination of Repeatedly Contaminated Surfaces, USNRDL–TR–59 (confidential).

[4] Strope, W. E., Protection and Decontamination of Land Targets and Vehicles, Operation Jangle, project 6.2, AFSWP–WT–400.

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[6] Molumphy, G. G., Captain, USN, Bigger, M. M., Proof Testing of AW Ship Countermeasures, Operation Castle final report, project 6.4, USNRDL 0012361.

[7] Lee, Hong, Technical Survey Data for Operation Castle, project 6.4, USNRDL TM–49.

[8] Maloney, Joseph C., et al., decontamination and protection, Operation Castle, project 6.5, AFSWP–WT–928.

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### Cost of Reclamation

Considerable data has been collected regarding the effectiveness of reclamation of targets contaminated by local fallout. The feasibility of applying these methods depends upon the following parameters:

(*a*) The time required to perform the reclamation must be short enough to make an appreciable saving in radiological exposure to mission personnel,

(*b*) The radiation exposure to reclamation personnel must be justified by the saving in exposure of mission personnel,

(*c*) The effort (manpower) and logistics required to reclaim the target must be compatible with the total effort available.

Thus, the cost of reclamation as measured in operating time, effort, radiation exposure, equipment, and supplies is an important determination.

It is impossible to generalize on these quantities for they are influenced by many factors.

The type of fallout, whether it be from a deep water, harbor or land detonation, influences the rate and/or method of decontamination. A deepwater-type fallout can be removed only to an extent of about 60 percent for a firehosing, scrubbing operation on ships,[1] the rate being about 40 square feet per minute. The same decontamination procedure at 6 times the rate of operation on a paved area contaminated by dry-land-type fallout will yield a removal of about 98 percent.[2] To achieve an equivalent removal on the ship, a surface removal technique would be required. Typical rates of operation are about 20 feet per minute for paint stripping[3] and about 7 feet per minute for removing a ⅛-inch thick layer of wood from the flight deck.[4]

The amount (or mass) of fallout on a surface influences the rate, particularly for harbor and dry-type fallout that must be transported over horizontal surfces for considerable distances. The following table shows an example of how the rate decreases with increasing masses of dry fallout for motorized flushing.[2]

| Dry fallout gm/ft:[2] | *Motorized flushing rate, ft.²/min.* |
|---|---|
| 10 | 670 |
| 33 | 650 |
| 100 | 580 |
| 330 | 300 |

The mass of fallout has no effect on the rate of operation for surface removal or earth moving techniques.

The rate of operation is influence by the surface characteristics of the target, rough surfaces, e. g., wood shingles, requiring longer time than smooth, e. g., metal surfaces. The following table is an example of the influence of surface roughness on rate of operation:[2]

*Firehosing of dry contaminant*

| Material | Effectiveness (percent removed) | Rate (ft²/min/hose) |
|---|---|---|
| Corrugated metal | 97 | 65 |
| Composition shingles | 95 | 50 |
| Wood shingles | 89 | 35 |

The rate of reclamation by earth moving is influenced by soil characteristics. Standard earth moving practice has developed considerable information on this subject.

---

[1] AFSWP, ITR 1323, preliminary report, Operation Redwing, project 2.9, Standard Recovery Procedure for Tactical Decontamination of Ships. Confidential.

[2] Field Evaluation of Cost and Effectiveness of Basic Decontamination Procedures for Land Target Components, Sartor, J. D., Curtis, H. B., etc., USNRDL–TR in preparation. Unclassified.

[3] Rates approaching 50 square feet per minute are possible if removal of only the surface layer of paint gives the required reduction in radiation intensity.

[4] Proof Testing of AW Ship Countermeasures, Operation Castle, project 6.4 WT-927, Molumphy, Bigger. Confidential.

The degree of mechanization obviously influences rate of operation. The following example compares firehosing rate with that of motor flushing for harbor-type fallout. Also shown are the influence of mechanization on effort and radiation exposure.[2][5]

| Criteria for comparison | Actual performance or cost | | |
|---|---|---|---|
| | Firehosing | Motorized flushing | Relative cost FH/MF |
| 1. Operating rate per unit, hr/$10^6$ ft$^2$ | 222 | 30 | 7.4 |
| 2. Personnel required per unit | 5½ | 2 | 2.75 |
| 3. Effort (direct labor), man-hr/$10^6$ ft$^2$ | 1,210 | 60 | 20.0 |
| 4. Radiation shielding factor | 1.0 | 0.5 | 2.0 |
| 5. Relative cost in radiation dose | 1,210 | 30 | 40.0 |

Target complexity obviously influences rate of operation. For optimum performance, spacings between target components must be large enough to permit mechanized equipment to be used.

A simplified example will help indicate the time, manpower, and basic supplies required for recovery of a target complex. The following criteria are assumed:

(*a*) Target: City of San Francisco.
(*b*) Fallout: Harbor-type at 33 gms/ft$^2$.
(*c*) Area to be recovered: About 25 square miles consisting of—
1. All paved areas.
2. All industrial and commercial areas and buildings.
3. 50 percent of the park areas.
4. 10 percent of the residential areas and buildings.

(*d*) Methods: Firehosing and earth moving.

The following table indicates an estimate[5] of the cost of reclaiming these critical areas:

*Cost of decontaminating critical areas of San Francisco through use of available firefighting and earth moving equipment for removing slurry contaminant*

| | Firehosing | | | Earth moving, land areas | Grand total |
|---|---|---|---|---|---|
| | Roofs | Paved surfaces | Subtotal | | |
| 1. Time to complete decontamination (24-hour days) | 16.8 | 11.7 | 28.5 | 13 | ---------- |
| 2. Direct labor (number of men) | ---------- | ---------- | 4,000 | 2,800 | 6,800 |
| 3. Total labor, direct and support (number of men) | ---------- | ---------- | 6,000 | 4,900 | 10,900 |
| 4. Total effort (8-hour man-days) | $101\times10^3$ | $70\times10^3$ | $171\times10^3$ | $64\times10^3$ | $235\times10^3$ |
| 5. Labor cost at $10 per man-day | ---------- | ---------- | $1.71\times10^6$ | $0.64\times10^6$ | $2.35\times10^6$ |
| 6. Water required for decontamination (gallons) | $362\times10^6$ | $314\times10^6$ | $676\times10^6$ | ---------- | ---------- |
| 7. Fuel required (gallons): | | | | | |
| (*a*) Gasoline | 145,000 | 101,000 | 246,000 | 95,000 | 341,000 |
| (*b*) Diesel fuel | ---------- | ---------- | ---------- | 195,000 | 195,000 |

As can be seen, the reclamation is feasible in what appears to be a reasonable time. The amount of equipment required is within the capability of existing sources in San Francisco. The manpower is not too excessive considering the numbers of people available. The water requirements are within the capability of the normal supply. Fuel consumption is less than normal daily requirements. The greatest problem would undoubtedly be that of organizing, training, supervising, and controlling 11,000 men.

Automatic decontamination devices such as the washdown system have, as an important advantage, the capability of reclamation at very early times with no expenditure of manpower or radiation exposure. They can be extremely effective (i. e., removal of 90–95 percent) even on sea-water-fallout.[4] However, they do require expenditure of funds before the war begins.

[5] Engineering Approach to Radiological Decontamination, Hawkins, M. B. (Paper to be given ASME semiannual meeting, San Francisco, June 1957.) Unclassified.

# THE NATURE OF RADIOACTIVE FALL-OUT AND ITS EFFECTS ON MAN

# HEARINGS

BEFORE THE

## SPECIAL SUBCOMMITTEE ON RADIATION

OF THE

## JOINT COMMITTEE ON ATOMIC ENERGY
## CONGRESS OF THE UNITED STATES

EIGHTY-FIFTH CONGRESS

FIRST SESSION

ON

THE NATURE OF RADIOACTIVE FALLOUT AND ITS EFFECTS ON MAN

JUNE 4, 5, 6, AND 7, 1957

**PART 2**

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## APPENDIX 10

OAK RIDGE NATIONAL LABORATORY,
*Oak Ridge, Tenn., August 21, 1957.*

Mr. JAMES T. RAMEY,
*Executive Director, Joint Committee on Atomic Energy,*
*Washington, D. C.*

DEAR MR. RAMEY: Enclosed please find a copy of the material concerning topic VIII D of the outline, fallout and water decontamination, requested by Congressman Holifield for the Joint Committee on Atomic Energy Report.

Enclosed is the biographical sketch also requested in your letter of June 19, 1957.

If I can be of any further assistance to you and the committee, please feel free to write.

Thank you.

Very truly yours,

WILLIAM J. LACY,
*ERDL Representative at ORNL.*

Enclosures: 1. Report on Fallout. 2. Biographical sketch.

Cc: Commanding Officer, Engineer Research and Development Labs, Fort Belvoir, Virginia; Harry N. Lowe, Jr., Chief Sanitary Engineering Branch, Fort Belvoir, Virginia; Dr. Karl Z. Morgan, Director, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

### BIOGRAPHICAL SKETCH

William J. Lacy was born in 1928 in Wallingford, Connecticut, attended Lyman Hall High School where he won the prizes in science and chemistry, then he obtained a B. S. degree in 1950 from the University of Connecticut where he majored in Chemistry. He entered graduate school at New York University in September of 1950 and worked as a research associate on an AEC research contract. In May of 1951 he joined the staff at the Engineer Research and Development Labs of Fort Belvoir, Virginia, and immediately was transferred to the Oak Ridge National Laboratory to work on the water decontamination research project.

He has had seven (7) articles published, presented numerous papers and is a member of the American Chemical Society, American Association for the Advancement of Science and the Scientific Research Society of America.

Mr. Lacy is married and has two (2) sons, 2½ and six months, he resides in Oak Ridge, Tennessee.

[Material for Joint Committee on Atomic Energy Topic VIII D]

### REMOVAL OF RADIOACTIVE FALLOUT FROM CONTAMINATED WATER SUPPLIES

William J. Lacy, Chemist,* Sanitary Engineering Branch, Engineer Research and Development Labs, Fort Belvoir, Va.

There are two possible sources of radioactive contamination of public water supplies, (1) the result of direct discharge into the environment from reactor processing plants, research center using radioisotopes and others and (2) deposition of radioactive material by fallout or wash-in due to weapon's test activities.

Most of the radioactive materials in item one are in solution, fallout, however, may be in the form of insoluble oxides, and its removal may differ from the removal of ionic material.

Studies have been reported on the subject of fallout in particular areas (1), (2), (3), (4). It was reported that 35 percent of the fallout activity was removed by the Albany, New York, water treatment plant, an alum coagulation, settling and filtration plant. Thomas and his coworkers at Harvard (2) (3) working at the Lawrence, Massachusetts, water plant obtained 80 percent removal by coagulation, settling, and filtration. Bell (4) compared the fallout removal results from Cambridge and Lawrence, Massachusetts, and Rochester, New York, with pilot plant results obtained by Straub (5) (6) who used a simulated bomb blast mixture with an age about one month after detonation.

*On loan to Health Physics Division, Oak Ridge National Lab., Oak Ridge, Tennessee.

The comparison indicated the three treatment plants show much lower removals of fallout than Straub obtained on chemical processed radioactive material even though the same procedure was used in both cases. The U. S. P. H. S. reported the analysis of rain water samples containing fallout showed 50 to 100 percent of the "old" radioactive material to be soluble. However, the soluble fraction dropped to about 30 percent during the weapon's testing period.

For reactor made fission products, or a mixture of commercially available radioisotopes, the efficiency of removal would be a function of the various radioelements comprising the mixture. Results in laboratory studies and pilot plant scale investigations by the author indicates removals of about 70 to 85 percent using either alum and soda ash or ferric chloride and limestone coagulants. A series of studies (7) reported that removals of 99 percent could be obtained using a serial coagualtion procedure including an excess lime-soda ash softening or phosphate coagulation step, provided some clay material was added to remove radiocesium.

Conventional wastes treatment processes include coagulation, settling, and filtration, plus disinfection. Often additional treatment, such as fluoridation, aeration, softening, ion exchange, iron and manganese removal are employed.

During coagulation certain of the dissolved constituents are precipitated as insoluble hydroxides or carried along, scavenged, with the heavy metal hydroxides of alum or iron. Coagulation can have its radioactivity removal increased from about 75 percent to almost 90 percent by the addition of clay for cesium and copper sulfate for radioiodine.

It should be pointed out that different radioisotopes respond differently to removal by coagulation. Other factors to be considered include: (1) Chemical and physical form of the radionuclide, (2) concentration or the radioactive material, and (3) optimum pH of flocculation for the coagulant available and the water under treatment. Investigation by the author (8) indicates increase dosages of chemical generally yielded only slightly higher removals while higher pH usually resulted in proportionately higher removals.

Softening using lime-soda ash is one of the more effective chemical methods for the removal of radiostrontium and barium. However, it is necessary to use excesses quantities, over the stoichiometric dosage, for satisfactory results. Studies at MIT (9) (10) have indicated that the radiostrontium is removed by coprecipitation with the hardness or calcium carbonate in a mixed crystal formation.

Ion exchange is another method used by some municipal water treatment plants. Removal of ionic radionuclides by this process is not only technically possible (11), but very satisfactory. The most effective method employes either a mixed bed principal or separate cation-anion exchange columns. Ion exchange units such as home-type water softeners are very effective for removal of $99^{+}$ percent of the radioactive fallout or reactor originated radionuclides from contaminated water. Also ion exchange resins (mixed) can be used with, good results, as slurries for the removal of a vaniety of radioactive contaminants from water solutions (12)

Other methods, such as, the use of clays, powdered metal, charcoal, flotation and various adsorbents all have some merit for the removal of specific radioisotopes or under a given set of condition result in good removals. (13) However, clay seems to have the most practical and over advantage of being (1) available, (2) cheap, (3) effective, (4) simple to use, (5) easy to remove both absorbent and absorber and the radioactive material will not be easily leached once it is attached to the clay particle. Distillation although not a usual municipal water treatment method is used extensively by the military on island bases and where a high quality of water is required. Distillation results in the best single treatment of a contaminated water removing $99.9^{+}$ percent. (14) The major objection to distillation as a water treatment procedure is cost.

As indicated by the literature cited most of the above studies have been made on chemically processed, radiochemically pure radioisotopes and not true fallout from a nuclear detonation. Therefore, it was expected that the actual fallout material not being entirely in the same physical and chemical form could not be as readily removed from contaminated water. However, recent tests by the Corps of Engineers at the AEC Nevada Proving Grounds on some very low level fallout indicated (1) close agreement with laboratory results on removal by coagulation and softening using lime-soda ash and precipitation with trisodium phosphate at a high pH, (2) the ion exchange procedures resulted in 99 to 100 percent removal of the bomb fallout material, (3) the material that was not

a true solution could be removed physically and the material in solution treated chemically and (4) radionuclide once adsorbed on clays were not appreciably leached by tap water.

Many other experiments have been made by myself and others, some are still in progress, which have not been cited here. It is felt that this brief general review plus the six tables showing detailed data, will give the committee a review of the field on water decontamination.

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TABLE I.—*Coagulation for removal of radioactivity*

| Contaminant | Dosage, p. p. m. | Percent removal | |
|---|---|---|---|
| | | $FeCl_3$–$CoCO_3$ | Alum-soda ash |
| $Ce^{144}$–$Pr^{144}$ | 50 | 99.2 | 96.1 |
| | 100 | 99.4 | 96.5 |
| $Ba^{140}$–$La^{140}$ | 50 | 67.4 | 58.4 |
| | 100 | 70.7 | 58.0 |
| $Zr^{95}$–$Nb^{95}$ | 50 | 98.1 | 76.4 |
| | 100 | 98.8 | 78.6 |
| $I^{131}$ | 50 | 45.0 | 26.3 |
| | 100 | 63.0 | 35.7 |
| $P^{32}$ | 45.7 | 93.3 | 94.1 |
| MFP-1 [1] | 29–58 | 60–83.7 | ---------- |
| MFP-2 [2] | 50 | 70.1 | 72.6 |

[1] MFP-1—ORNL waste containing mixed fission products.
[2] MFP-2—Simulated 30-day atomic-bomb blast mixture.

TABLE II.—*Results of lime-soda ash treatment for removal of strontium*

| Treatment | Percent removal of activity |
|---|---|
| Stoichiometric amounts | 75.0 |
| 20 ppm excess lime-soda ash | 77.0 |
| 50 ppm excess lime-soda ash | 80.1 |
| 100 ppm excess lime-soda ash | 85.3 |
| 150 ppm excess lime-soda ash | 97.3 |
| 200 ppm excess lime-soda ash | 99.4 |
| 300 ppm excess lime-soda ash | 99.7 |

TABLE III.—*Ion exchange column for water decontamination*

| Run No. | Resin* | Contaminant | Resin capacity gal./ft.$^3$ | Percent removal until breakthrough |
|---|---|---|---|---|
| 1 | Cation | MFP-1 | 5,700 | 71–82 |
| 2 | Mixed bed | MFP-1 | 3,150 | 93–99+ |
| 3 | Cation | MFP-2 | 6,000 | 88–96 |
| 4 | Mixed bed | MFP-2 | 2,890 | 96–99 |
| 5 | Cation | $Zr^{95}$–$Nb^{95}$ | 6,750 | 85–88 |
| 6 | Mixed bed | $Zr^{95}$–$Nb^{95}$ | 2,600 | 92–97 |
| 7 | Cation | MFP-3 | 3,270 | 85–90 |
| 8 | Mixed bed | MFP-3 | 6,150 | 92–99 |

*Cation resin was a high capacity nuclear sulfonic acid type and mixed bed was amberlite MB-3.

NOTES

MFP-1—ORNL liquid waste material.
MFP-2—Simulated 30-day atomic-bomb debris.
MFP-3—Three year old dissolved reactor fuel element.

TABLE IV.—*Removal of radioactive contaminants from water—Resin-jar test studies (stirring time, 90 minutes, samples filtered)*

| Contaminant | Initial pH | Initial activity c/m/ml | Percent removal mixed ion exchange resin, p. p. m. | | | |
|---|---|---|---|---|---|---|
| | | | 450 | 900 | 1,800 | 2,700 |
| $P^{32}$ | 8.2 | 5,560 | 47.4 | 74.5 | 96.2 | 99.8 |
| $Cd^{115}$ | 8.0 | 7,880 | 37.9 | 45.6 | 91.1 | 99.99 |
| $Cs^{137}$–$Ba^{137}$ | 8.2 | 8,200 | 15.1 | 14.6 | 69.1 | 99.99 |
| $Zr^{95}$–$Nb^{95}$ | 8.1 | 6,700 | 98.3 | 98.4 | 99.2 | 99.4 |
| $I^{131}$ | 7.5 | 8,200 | 84.5 | 93.5 | 95.6 | 98.1 |
| $Ce^{141}$, $^{144}$–$Pr^{144}$ | 7.9 | 4,150 | 98.7 | 99.2 | 99.8 | 99.98 |
| $Ba^{140}$–$La^{140}$ | 7.6 | 3,490 | 85.1 | 94.5 | 98.8 | 99.9 |
| FPM-4 | 8.3 | 13,600 | 82.7 | 90.5 | 97.3 | 99.2 |
| FPM-5 | 2.7 | 3,400 | 38.4 | ---- | ---- | ---- |

NOTES

FPM-4—Iodine dissolver solution aged 30 days.
FPM-5—Mixed fission product waste containing mainly $Cs^{137}$–$Ba^{137}$ and $Ru^{106}$–$Rh^{106}$.

TABLE V.—*Decontamination of radioactively contaminated water by slurrying with clay*

| Contaminant | pH | Clay concentration, p. p. m. 1,000 | 3,000 |
|---|---|---|---|
| | | Percent removal | |
| $Ru^{106}$–$Rh^{106}$ | 5.2 | 50.5 | 61.5 |
| $Zr^{95}$–$Nb^{95}$ | 7.5 | 98.0 | 99.4 |
| $Sr^{90}$–$Y^{90}$ | 7.7 | 83.4 | 92.9 |
| $I^{131}$ | 7.5 | 4.9 | 3.4 |
| $Ce^{141,144}$–$Pr^{144}$ | 8.0 | 99.7 | 99.9 |
| $Ba^{140}$–$La^{140}$ | 7.8 | 88.8 | 94.3 |
| MFP-1 | 8.8 | 82.0 | 86.3 |
| MFP-2 | 9.0 | 70.0 | 72.8 |
| MFP-3 | 7.7 | 79.0 | 83.6 |

TABLE VI.—*Removal of radioactive material by distillation (60 gallon/hr thermocompression unit)*

| Run No. | Contaminant | Activity of feed, d/m/ml | Removal of activity expressed as decontamination factor | Percent |
|---|---|---|---|---|
| 1 | MFP-1 | 22,060 | $4.10 \times 10^3$ | 99.98 |
| 2 | MFP-2 | 97,400 | $4.97 \times 10^3$ | 99.98 |
| 3 | MFP-3 | 31,150 | $3.59 \times 10^3$ | 99.97 |
| 4 | MFP-4 | 62,400 | $3.52 \times 10^2$ | 99.72 |
| 5 | $Pa^{233}$ | 41,030 | $2.31 \times 10^3$ | 99.96 |
| 6 | $I^{131}$ | 60,900 | $7.04 \times 10^2$ | 99.86 |
| 7* | MFP-5 | 38,910 | $1.09 \times 10^3$ | 99.91 |
| 8* | MFP-4 | 69,700 | $1.00 \times 10^4$ | 99.99 |
| 9* | MFP-1 | 12,020 | $1.70 \times 10^4$ | 99.99 |
| 10* | $I^{131}$ | 45,600 | $1.28 \times 10^3$ | 99.92 |
| 11* | $Pa^{233}$ | 25,300 | $5.80 \times 10^3$ | 99.98 |

*Glass wool reflux condenser used.

NOTES

MFP-1 was 3-year-old fission product mixture.
MFP-2 was a 2-week-old mixture from disolution of a reactor slug.
MFP-3 was composite sample or ORNL liquid waste.
MFP-4 concentrate from ORNL liquid waste evaporator.
MFP-5 mixture to simulate the material expected 10 days after atomic detonation.

## APPENDIX 11

UNITED STATES ATOMIC ENERGY COMMISSION,
*Washington 25, D. C., August 20, 1957.*

HON. CHET HOLIFIELD,
*Chairman, Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, House of Representatives, Congress of the United States.*

DEAR MR. HOLIFIELD: At the suggestion of your Committee, the Division of Biology and Medicine, U. S. Atomic Energy Commission, invited the principal participants in the discussions involving predictions of future skeletal concentrations of strontium 90 in humans which took place at the recent Congressional Hearings on fallout to meet once again in an attempt, insofar as present information permitted, to reduce the degrees of uncertainty in these predictions.

This meeting took place on July 29, 1957 and I am pleased to transmit a summary report of the meeting based on the stenographic transcript and consultation with the principal participants. This report was prepared by Dr. Forrest Western, of the Division of Biology and Medicine. It is my opinion this report honestly and clearly reflects the views of the participant scientists with respect to this problem. This document, then, would appear to reflect the thinking of those scientists who have worked hardest and thought most on the subject of these predictions, and should, therefore, be a useful addition to the text of the very important and

## Arguments Against Civil Defense and a Rebuttal

Some of the arguments made against civil defense were parodied as follows in a piece in the Harvard Crimson in 1962:

Recommendations by the Committee for a Sane Navigational Policy:

It has been brought to our attention that certain elements among the passengers and crew favor the installation of lifeboats on this ship. These elements have advanced the excuse that such action would save lives in the event of a maritime disaster such as the ship striking an iceberg. Although we share their concern, we remain unalterably opposed to any consideration of their course of action for the following reasons:

1. This program would lull you into a false sense of security.

2. It would cause undue alarm and destroy your desire to continue your voyage in this ship.

3. It demonstrates a lack of faith in our Captain.

4. The apparent security which lifeboats offer will make our navigators reckless.

5. These proposals will distract our attention from more important things, e.g., building unsinkable ships. They may even lead our builders to false economies and the building of ships which are actually unsafe.

6. In the event of being struck by an iceberg (we will never strike first) the lifeboats would certainly sink along with the ship.

7. If they do not sink, you will only be saved for a worse fate, inevitable death on the open sea.

8. If you should be washed ashore on a desert island, you could not adapt to the hostile environment and would surely die of exposure.

9. If you should be rescued by a passing vessel, you would spend a life of remorse mourning your lost loved ones.

10. The panic caused by a collision with an iceberg would destroy all semblance of civilized human behavior. We shudder at the prospect of one man shooting another for the possession of a lifeboat.

11. Such a catastrophe is too horrible to contemplate. Anyone who does contemplate it obviously advocates it.

# A. R. P.

(Air Raid Precautions)

by

J. B. S. HALDANE, F.R.S.

(Co-inventor of 1915 gas masks)

SEPTEMBER
1938

LONDON

VICTOR GOLLANCZ LTD

1938

keyholes and cracks in the wall or between the floor-boards are to be filled with putty or sodden newspaper.

The windows must be specially protected against breakage by blast or splinters.

(Plastic sheets and duct tape for broken windows)

How far are these precautions effective? In 1937 a committee of the Cambridge Scientists' Anti-War Group published a book[1] in which it was stated that no ordinary room is anywhere near gas-proof.

[1] *The Protection of the Public from Aerial Attack.*

Error of Cambridge Scientists' Anti War Group:



The real criticism is as follows. It is unlikely that there would be a lethal concentration of gas out of doors for a long period. The wind carries gas away, and in cities there are vertical air currents even in calm weather. If many tons of bombs could be dropped in the same small area either at once or in succession this would not be so. But given any sort of defence bombs will be dropped more or less at random.

Suppose we had out of doors during 10 minutes a phosgene concentration of one part in 10,000, which would be fatal in a few breaths to people in the street, the concentration inside would never rise as high as $\frac{1}{15}$ of this value[1] if the leakage time were $2\frac{1}{2}$ hours, which is rather low. (Hence protection factor = 15)

[1] Since 10 minutes is $\frac{1}{15}$ of $2\frac{1}{2}$ hours.

Many of the questions which are asked concerning Air Raid Precautions are unanswerable in the form in which they are put. If I am asked "Does any gas mask give complete protection against phosgene" the only literally true answer is "No." One could not live in a room full of pure phosgene in any of them. And one would be killed if a hundred-pound phosgene bomb burst in the room, even when wearing the very best mask. But one would be safe in a phosgene concentration of one part per thousand, of which a single breath would probably kill an unprotected man. Hence in practice such a mask is a very nearly complete protection.



1. NON-PERSISTENT GASES, such as phosgene. They can be dropped in bombs which burst, and suddenly let loose a cloud of gas, which is poisonous when breathed, but which gradually disperses. If there is a wind the dispersal is very quick; in calm, and especially in foggy weather, it is much slower. These gases can penetrate into houses, but very slowly. So even in a badly-constructed house one is enormously safer than in the open air. Even the cheapest type of gas mask, *provided it fits properly and is put on at once*, gives good protection against them (see Chapter IV).

2. PERSISTENT GASES, such as mustard gas. Mustard gas is the vapour of an oily liquid, which I shall call mustard liquid. So far as I know this has not been dropped from aeroplanes in bombs on any great scale. It was used very effectively by the Italians in Abyssinia, who sprayed it in a sort of rain from special sprayers attached to the wings of low-flying aeroplanes.

If the mustard liquid could be sprayed evenly, things would be far more serious. All the outside air of a large town would be poisonous for several days. But this would only be possible if the spraying aeroplanes could fly to and fro over the town in formation, and at a height of not more than 300 feet or so. A fine rain of mustard liquid would probably evaporate on its way to the ground, or blow away, if it were let loose several thousand feet up in the air. Spraying from low-flying aeroplanes was possible in Abyssinia because the Abyssinians had no anti-aircraft guns and no defensive aeroplanes. It would probably not be possible in Britain.

THE HAMBURG DISASTER. Fantastic nonsense has been talked about the possible effects of gas bombs on a town. For example, Lord Halsbury said that a single gas bomb dropped in Piccadilly Circus would kill everyone between the Thames and Regent's Park. Fortunately, although no gas bombs have been dropped in towns in war-time, there are recorded facts[1] which give us an idea of what their effect would be. On Sunday, May 20th, 1928, at about 4.15 p.m., a tank containing 11 tons of phosgene burst in the dock area of Hamburg.

Casualties occurred up to six miles away. In all 300 people were made ill enough to be taken to hospital, and of these ten died. About fifty of the rest were seriously ill. These casualties are remarkably small.

[1] Hegler, *Deutsche Medizinische Wochenschrift*, 1928, p. 1551.

## WHY GAS WAS NOT USED IN SPAIN

In view of the terrible stories as to the effects of gas, many people are surprised that it has not been used in Spain. First, why was it not used against the loyalist army? Secondly, why was it not used against towns? The soldiers had respirators after about February 1937, but were not well trained in their use, and often lost them. Very few civilians had any respirators at all.

Gas was not used in the field for several reasons. The main reason is that the number of men and guns per mile was far less than on the fronts in the Great War. Gas is effective if you have a great deal of it,



but the amount needed is enormous. Thus during the night of March 10-11th, 1918, the Germans fired about 150,000 mustard-gas shells into an area of some twenty square miles south-west of Cambrai. If most of the air in a large area is poisoned the effects are serious. But if a few gas shells are fired or a few cylinders let off, the gas soon scatters and ceases to be poisonous, and a man can often run to a gas-free place, even without a mask, before he is poisoned.

Gas was not used against the towns for this reason, and for another, which is very important. Gas only leaks quite slowly into houses, particularly if there are no fires to make a draught, and draw in outside air; and there is very little fuel in loyal Spain.

### PANIC

Panic can be a direct cause of death. If too many people crowd into a shelter, especially one with narrow stairs leading to it, they may easily be crushed to death. In January 1918 fourteen people were killed in this way at Bishopsgate Station in London, and sixty-six were killed in a panic in one of the Paris Underground stations as the result of a false gas alarm.

(Bishopsgate Station incident: 28 January 1918)

### BACTERIA AND OTHER MICROBES

It is possible that these will be used in some kind of spray or dust. The difficulty is a technical one. It is easy to disperse many solids as smoke. But this needs heat, and cooked bacteria are harmless. Many



bacteria are killed even by drying. And once bacteria are on the ground they generally stay there. Possibly pneumonic plague or some other air-borne disease might be started by a dust-bomb. Cholera bacilli might be dropped in a reservoir. But they would probably be stopped by filters, and even without this would be likely to die before they reached the houses.

A million fleas weigh very little, and could easily be dropped. In theory they could be infected with plague. In practice this would need a staff of hundreds of trained bacteriologists, and huge laboratories. So with other possible means of infection. Some may very well be tried, if only to create a panic, but I would sooner face bacteria than bombs.

Certain pacifist writers are severely to blame for our present terror of air raids. They have given quite exaggerated accounts of what is likely to happen.



So long as civilian populations are unprotected, criminal States will continue to murder the citizens of their weaker neighbours and to blackmail the stronger.



PHYSICAL PROPERTIES OF A GAS-CLOUD. Every student of chemistry learns that a heavy gas such as chlorine can be poured from one vessel into another almost like water, whilst a light gas such as hydrogen rapidly rises. Now all the poisonous gases and vapours used in war are heavier than air, so it is thought that they would inevitably flood cellars and underground shelters, and that on the first floor of a house one would not be safe.



But within a short time it would be mixed with many times its volume of air. Now air containing one part in 10,000 of phosgene is extremely poisonous. But its density exceeds that of air by only one part in 4,000.

# GAS-MASKS, AND GAS-PROOF BAGS FOR BABIES

THE EARLIEST GAS-MASKS made in 1915, relied on chemical means to stop chlorine, which was the first gas used. A cloth soaked with sodium phenate or various other compounds will stop chlorine on its way through. But it would not stop carbon monoxide, mustard gas, or many other gases. The terrible prospect arose that it would be necessary to devise a new chemical to stop each new gas. There would be a continual series of surprise attacks with different gases, each successful until a remedy was found, and each involving the death of thousands of men.

It is a most fortunate fact that the majority of vapours can be removed from air, not by chemical combination, but by a process called adsorption, which is non-specific. For example lime will stop an acid gas such as carbon dioxide, and woollen cloth soaked in acid will stop an alkaline gas such as ammonia. No single chemical will combine with both.

But charcoal, silica, and various other substances, when properly prepared, will take up vapours of different chemical types. The molecules form a very thin liquid layer on the surface of the adsorbent, as indeed they do on glass or metals. But charcoal is full of pores and has an enormous surface per unit of weight; so it can take up a great deal of gas.

The main characteristic in a vapour which renders it adsorbable is that it should be the vapour of a liquid with a high boiling point. Thus carbon monoxide boils at–190° C, and is hardly adsorbed at all. Phosgene boils at 8° C and is fairly easily adsorbed. Mustard gas boils at 217° C and is very easily adsorbed indeed. This has a lucky consequence. It is quite sure that there are no unknown poisonous gases with a boiling point as low as that of carbon monoxide. For only a substance with very small molecules can have so low a boiling point. And chemists have made all the possible types of very small molecules. It is unlikely that there are any unknown poisonous gases with as low a boiling point as phosgene, though it is just possible. But if there are they will probably be stopped by charcoal. There may very possibly be some vapours of high boiling point more poisonous than mustard gas. But if so I am prepared to bet a thousand to one that charcoal will stop them all.

FINAL REPORT

11 March 1963

# Recovery and Decontamination Measures after Biological and Chemical Attack

This report has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense.

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by

Science Communication, Inc.
1079 Wisconsin Avenue, N.W.
Washington 7, D. C.

To plan for countermeasures against any weapons one must understand the problem—the nature, the potentials, and the limitations. This research project and the resultant final report were intended to bring together current information most applicable to civil defense. It was particularly intended for those who are responsible for planning preparatory, reclamation and countermeasures effort to minimize the damage from a BW/CW attack.

William J. Lacy
Project Coordinator
Postattack Research

## Decontaminants

An important class of decontaminants comprises the common substances or natural influences such as time, air, earth, water, and fire.

### Natural Effects

Biological agents are living organisms and tend to die off with time unless they are in a favorable environment with moisture, food, warmth, and other factors necessary for their survival. In addition, most biological organisms are very sensitive to the conditions of temperature and humidity -- and, particularly to the ultra-violet portion of sunlight. Adverse exposure to the elements -- air, sunlight, high temperature, low humidity -- is effective, in fact, against all biological agents except the spore forms of bacterial organisms.

It is generally assumed that in the vegetative form bacteria (as contrasted to the spore form) can persist for less than two hours during daytime and about eighteen hours at night. Since these short-lived bacteria are the most probable agents, outdoor decontamination is usually not called for unless the agent has been identified, either by laboratory tests or by the character of the disease, as one which forms spores or is otherwise known to be persistent.

The persistent, low-volatile, agents such as the liquid nerve agents (V-agents) and the blister gases present the principal chemical decontamination problem. Even these evaporate in time. The speed of evaporation and dissipation is enhanced by higher temperatures and wind. Thus, if it is possible to avoid the area or the use of contaminated objects for a reasonable length of time, decontamination may be unnecessary. Such periods might run from hours to a few days, depending on the degree of contamination and weather conditions. In cold weather the agents will persist for longer periods.

Water

Next to weathering, the most important natural decontaminant is water, used either to remove the agent, with or without soap or detergents to assist, or by boiling. One caution -- water used to wash away contamination becomes contaminated and must be disposed of accordingly. Boiling destroys most chemical agents and all biological agents. When it is feasible, boiling is one of the most generally desirable methods -- particularly for household use by individuals.

Earth and fire, the other natural decontaminants, would have relatively little application in civil defense BW/CW decontamination operations. Earth may be used to cover contamination temporarily to keep it out of contact with people while natural processes either dissipate or destroy the agent. This involves substantial effort with bulldozers and earth-moving equipment and usually is neither practical or necessary.

Chemical Decontaminants

These are preferred when they are available. Chemical decontaminants fall in two classes -- those which destroy or neutralize the agents, and those which simply assist in their removal.

The principal decontaminants which destroy or neutralize are:

- Chlorine-containing materials, such as calcium hypochlorite (HTH) and sodium hypochlorite solutions. Many household disinfectants available under various brand names -- Clorox, Purex, etc. -- are sodium hypochlorite solutions.

- Alkalies, such as caustic soda (lye) and sodium carbonate (washing soda, or soda ash).

The chlorine-containing materials, in proper concentrations, are effective against both biological and chemical agents. As solutions they are used to decontaminate surfaces, as in washing off sealed food containers; for decontaminating cotton fabrics by soaking or addition during the washing process; and for sterilizing water. Hypochlorite solutions have the disadvantage of corroding metals and so must be rinsed off thoroughly.

The hypochlorites -- calcium and sodium -- are the preferred decontaminants for blister gases and liquid nerve agents. For most such applications they are used as solutions but for vertical surfaces or porous surfaces a "whitewash" of calcium hypochlorite (HTH), hydrated lime, and water (called a "slurry") is more effective

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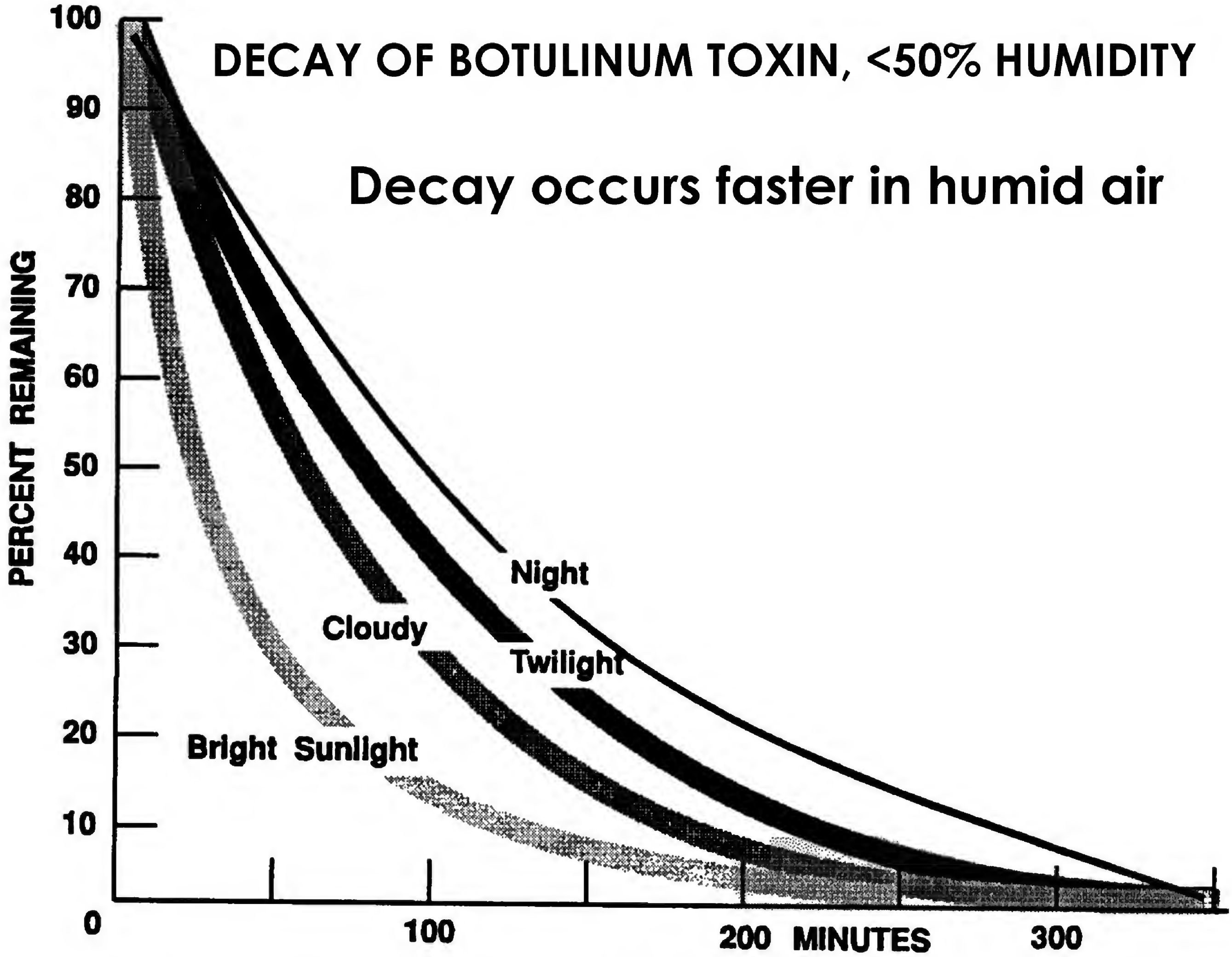
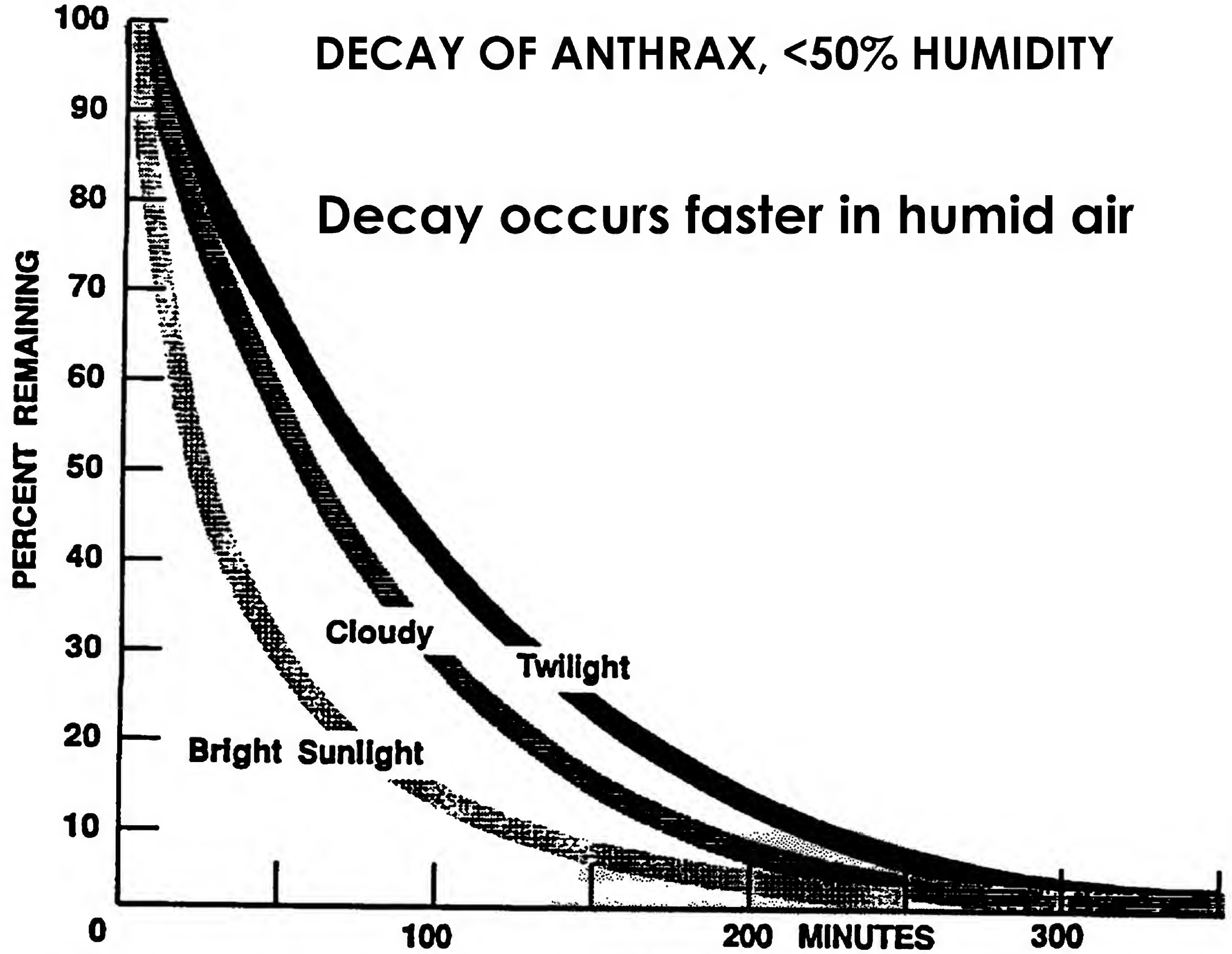



U.S. Army Field Manual FM 3-3 (1992), Fig. B-3.




U.S. Army Field Manual FM 3-3 (1992), Fig. B-1.

## Chemical and biological contamination avoidance, FM 3-3 (1992)

10 grams/square meter

*TABLE 1-2. Chemical Agent Persistency in Hours on CARC Painted Surfaces.*

| Temperature | | GA/ GF[1] | GB[2,3] | GD[2,3] | HD[1] | VX[2,3] |
|---|---|---|---|---|---|---|
| C° | F° | | | | | |
| -30 | -22 | * | 110.34 | 436.69 | ** | *** |
| -20 | -4 | * | 45.26 | 145.63 | ** | *** |
| -10 | 14 | * | 20.09 | 54.11 | ** | *** |
| 0 | 32 | * | 9.44 | 22.07 | ** | *** |
| 10 | 50 | 1.42 | 4.70 | 9.78 | 12 | 1776 |
| 20 | 68 | 0.71 | 2.45 | 4.64 | 6.33 | 634 |
| 30 | 86 | 0.33 | 1.35 | 2.36 | 2.8 | 241 |
| 40 | 104 | 0.25 | 0.76 | 1.25 | 2 | 102 |
| 50 | 122 | 0.25 | 0.44 | 0.70 | 1 | 44 |
| 55 | 131 | 0.25 | 0.34 | 0.51 | 1 | 25 |

NOTE

1 For grassy terrain multiply the number in the chart by 0.4.

2 For grassy terrain multiply the number in the chart by 1.75.

3 For sandy terrain multiply the number in the chart by 4.5.

* Agent persistency time is less than 1 hour.

** Agent is in a frozen state and will not evaporate or decay.

*** Agent persistency time exceeds 2,000 hours.

## COMPARATIVE VOLATILITY OF CHEMICAL WARFARE AGENTS

| Agent | Volatility (mg/m$^3$) at 25°C |
|---|---|
| Hydrogen cyanide (HCN) | 1,000,000 |
| Sarin (GB) | 22,000 |
| Soman (GD) | 3,900 |
| Sulfur mustard | 900 |
| Tabun (GA) | 610 |
| Cyclosarin (GF) | 580 |
| VX | 10 |
| VR ("Russian VX") | 9 |

Data source: US Departments of the Army, Navy, and Air Force. *Potential Military Chemical/Biological Agents and Compounds*. Washington, DC: Headquarters, DA, DN, DAF; December 12, 1990. Field Manual 3-9. Naval Facility Command P-467. Air Force Regulation 355-7.

## SIGNS AND SYMPTOMS REPORTED BY TOKYO HOSPITAL WORKERS TREATING VICTIMS OF SARIN SUBWAY ATTACKS*

| Symptom | Number/percentage of the 15 physicians who treated patients at UH | | Number/percentage of 472 care providers reporting symptoms at SLI | |
|---|---|---|---|---|
| Dim vision | 11 | 73% | 66 | 14% |
| Rhinorrhea | 8 | 53% | No information | |
| Dyspnea (chest tightness) | 4 | 27% | 25 | 5.3% |
| Cough | 2 | 13% | No information | |
| Headache | No information | | 52 | 11% |
| Throat pain | No information | | 39 | 8.3% |
| Nausea | No information | | 14 | 3.0% |
| Dizziness | No information | | 12 | 2.5% |
| Nose pain | No information | | 6 | 1.9% |

*Data reflect reported survey of self-reported symptomatology of physicians at the University Hospital of Metropolitan Japan emergency department and all hospital workers at Saint Luke's International Hospital exposed to sarin vapors from victims of the Tokyo subway attack.

SLI: Saint Luke's International Hospital

UH: University Hospital

Data sources: (1) Nozaki H, Hori S, Shinozawa Y, et al. Secondary exposure of medical staff to sarin vapor in the emergency room. *Intensive Care Med*. 1995;21:1032-1035. (2) Okumura T, Suzuki K, Fukuda A, et al. The Tokyo subway sarin attack: disaster management, Part 1: community emergency response. *Acad Emerg Med.* 1998;5:613-617. (3) Okumura T, Suzuki K, Fukuda A, et al. The Tokyo subway sarin attack: disaster management, Part 2: Hospital response. *Acad Emerg Med.* 1998;5:618-624.

**TABLE 21-3**

**MANAGEMENT OF MILD TO MODERATE NERVE AGENT EXPOSURES**

| | | Management | | | |
|---|---|---|---|---|---|
| | | Antidotes* | | Benzodiazepines (if neurological signs) | |
| Nerve Agents | Symptoms | Age | Dose | Age | Dose |
| • Tabun<br>• Sarin<br>• Cyclosarin<br>• Soman<br>• VX | • Localized sweating<br>• Muscle fasciculations<br>• Nausea<br>• Vomiting<br>• Weakness/floppiness<br>• Dyspnea<br>• Constricted pupils and blurred vision<br>• Rhinorrhea<br>• Excessive tears<br>• Excessive salivation<br>• Chest tightness<br>• Stomach cramps<br>• Tachycardia or bradycardia | Neonates and infants up to 6 months old | **Atropine** 0.05 mg/kg IM/IV/IO to max 4 mg or 0.25 mg AtroPen† and **2-PAM** 15 mg/kg IM or IV slowly to max 2 g/hr | Neonates | **Diazepam** 0.1–0.3 mg/kg/dose IV to a max dose of 2 mg, or **Lorazepam** 0.05 mg/kg slow IV |
| | | Young children (6 months old–4 yrs old) | **Atropine** 0.05 mg/kg IM/IV/IO to max 4 mg or 0.5 mg AtroPen and **2-PAM** 25 mg/kg IM or IV slowly to max 2 g/hr | Young children (30 days old–5 yrs old) | **Diazepam** 0.05–0.3 mg/kg IV to a max of 5 mg/dose or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg |
| | | Older children (4–10 yrs old) | **Atropine** 0.05 mg/kg IV/IM/IO to max 4 mg or 1 mg AtroPen and **2-PAM** 25–50 mg/kg IM or IV slowly to max 2 g/hr | Children (≥ 5 yrs old) | **Diazepam** 0.05–0.3 mg/kg IV to a max of 10 mg/dose or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg |
| | | Adolescents (≥ 10 yrs old) and adults | **Atropine** 0.05 mg/kg IV/IM/IO to max 4 mg or 2 mg AtroPen and **2-PAM** 25–50 mg/kg IM or IV slowly to max 2 g/hr | Adolescents and adults | **Diazepam** 5–10 mg up to 30 mg in 8 hr period or **Lorazepam** 0.07 mg/kg slow IV not to exceed 4 mg |

2-PAM: 2-pralidoxime
IM: intramuscular
IO: intraosseous
IV: intraveneous
PDH: Pediatrics Dosage Handbook
*In general, pralidoxime should be administered as soon as possible, no longer than 36 hours after the termination of exposure. Pralidoxime can be diluted to 300 mg/mL for ease of intramuscular administration. Maintenance infusion of 2-PAM at 10–20 mg/kg/hr (max 2 g/hr) has been described. Repeat atropine as needed every 5–10 minutes until pulmonary resistance improves, secretions resolve, or dyspnea decreases in a conscious patient. Hypoxia must be corrected as soon as possible.
†Meridian Medical Technologies Inc, Bristol, Tenn.
Data sources: (1) Rotenberg JS, Newmark J. Nerve agent attacks on children: diagnosis and management. *Pediatrics.* 2003;112:648–658. (2) Pralidoxime [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2002. (3) AtropPen (atropine autoinjector) [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2004. (4) Henretig FM, Cieslak TJ, Eitzen Jr EM. Medical progress: biological and chemical terrorism. *J Pediatr.* 2002;141(3):311–326. (5) Taketomo CK, Hodding JH, Kraus DM. *American Pharmacists Association: Pediatric Dosage Handbook.* 13th ed. Hudson, Ohio; Lexi-Comp Inc: 2006.

**TABLE 21-4**

**MANAGEMENT OF SEVERE NERVE AGENT EXPOSURE**

| | | Management | | | |
|---|---|---|---|---|---|
| | | Antidotes* | | Benzodiazepines (if neurological signs) | |
| **Nerve Agents** | **Severe Symptoms** | **Age** | **Dose** | **Age** | **Dose** |
| • Tabun<br>• Sarin<br>• Cyclosarin<br>• Soman<br>• VX | • Convulsions<br>• Loss of consciousness<br>• Apnea<br>• Flaccid paralysis<br>• Cardio-pulmonary arrest<br>• Strange and confused behavior<br>• Severe difficulty breathing<br>• Involuntary urination and defecation | Neonates and infants up to 6 months old | **Atropine** 0.1 mg/kg IM/IV/IO or 3 doses of 0.25mg AtroPen[†] (administer in rapid succession) and **2-PAM** 25 mg/kg IM or IV slowly, or 1 Mark I[†] kit (atropine and 2-PAM) if no other options exist | Neonates | **Diazepam** 0.1–0.3 mg/kg/dose IV to a max dose of 2 mg, or **Lorazepam** 0.05 mg/kg slow IV |
| | | Young children (6 months old–4 yrs old) | **Atropine** 0.1 mg/kg IV/IM/IO or 3 doses of 0.5mg AtroPen (administer in rapid succession) and **2-PAM** 25–50 mg/kg IM or IV slowly, or 1 Mark I kit (atropine and 2-PAM) if no other options exist | Young children (30 days old–5 yrs and adults | **Diazepam** 0.05–0.3 mg/kg IV to a max of 5 mg/dose, or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg |
| | | Older children (4–10 yrs old) | **Atropine** 0.1 mg/kg IV/IM/IO or 3 doses of 1mg AtroPen (administer in rapid succession) and **2-PAM** 25–50 mg/kg IM or IV slowly, 1 Mark I kit (atropine and 2-PAM) up to age 7, 2 Mark I kits for ages > 7–10 yrs | Children (≥ 5 yrs old) | **Diazepam** 0.05-0.3 mg/kg IV to a max of 10 mg/dose, or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg |
| | | Adolescents (≥ 10 yrs old) and adults | **Atropine** 6 mg IM or 3 doses of 2 mg AtroPen (administer in rapid succession) and **2-PAM** 1800 mg IV/IM/IO, or 2 Mark I kits (atropine and 2-PAM) up to age 14, 3 Mark I kits for ages ≥ 14 yrs | Adolescents and adults | **Diazepam** 5–10 mg up to 30 mg in 8-hr period, or **Lorazepam** 0.07 mg/kg slow IV not to exceed 4 mg |

IM: intramuscular
IO: intraosseous
IV: intravenous

*In general, pralidoxime should be administered as soon as possible, no longer than 36 hours after the termination of exposure. Pralidoxime can be diluted to 300 mg/mL for ease of intramuscular administration. Maintenance infusion of 2-PAM at 10–20 mg/kg/hr (max 2 g/hr) has been described. Repeat atropine as needed every 5–10 min until pulmonary resistance improves, secretions resolve, or dyspnea decreases in a conscious patient. Hypoxia must be corrected as soon as possible. [†]Meridian Medical Technologies Inc, Bristol, Tenn.

Data sources: (1) Rotenberg JS, Newmark J. Nerve agent attacks on children: diagnosis and management. *Pediatrics*. 2003;112:648–658. (2) Pralidoxime [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2002. (3) AtroPen (atropine autoinjector) [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2004. (4) Henretig FM, Cieslak TJ, Eitzen Jr EM. Medical progress: biological and chemical terrorism. *J Pediatr*. 2002;141(3):311–326. (5) Taketomo CK, Hodding JH, Kraus DM. *American Pharmacists Association: Pediatric Dosage Handbook*. 13th ed. Hudson, Ohio: Lexi-Comp Inc; 2006.

# FM 100-30

# NUCLEAR OPERATIONS

Headquarters, Department of the Army

Field Manual
100-30

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC, 29 October 1996

# NUCLEAR OPERATIONS

## CONTENTS



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# PREFACE

In the past, Soviet-styled armored echeloned formations were the primary threat to the United States (US). In response to this threat the US designed and stockpiled tactical nuclear weapons. Today's threats consist of regional instabilities and the proliferation of weapons of mass destruction (WMD). However, the US, as well as many other nations, actively pursues a policy of nonproliferation. Despite this, the number of nations who have, or are developing, nuclear weapons continues to grow. Therefore, the US may some day find itself confronted by an opponent who possesses nuclear weapons. Because of the continuing reduction in the size of US military forces, the US could also find itself opposed by an overwhelming conventional threat. Either scenario could lead to the use of nuclear weapons. Therefore, the US must concern itself with countering the proliferation of weapons of mass destruction.

Despite the continuing drawdown of US military forces, the current national military strategy includes fighting and winning two near-simultaneous regional wars with conventional forces. Any US threat of employing nuclear weapons is to deter a potential adversary's use of such weapons. If deterrence fails. the goal is to end hostilities on terms acceptable, at the lowest level of conflict, to the US and its allies. However, the US unilaterally reserves the right to use nuclear weapons if necessary. Use would be restricted, of course, with tight limits on the area and time of use. This would allow the belligerent to recognize the "signal" of limited response and to react accordingly.

The Army describes battlefield nuclear warfare (BNW) in terms of being able to conduct continuous combat operations in a nuclear environment. The presence of any nuclear-capable system, before, during, or after nuclear-weapons employment by either friendly or enemy forces, creates a nuclear environment. The implications of their very presence creates the nuclear environment.

Before 1991, the US Army had custody of tactical nuclear weapons which were to be employed, on Presidential release, by organic Army field artillery units. In September 1991, the Presidential Nuclear Initiative (PNI) removed the organic nuclear responsibility from the US Army. Today the Army neither has custody of nuclear weapons nor do corps and divisions employ them. The US Air Force or the US Navy are now responsible for delivery of nuclear weapons in support of Army operations. The Army retains its role in nominating nuclear targets and is also responsible for nuclear force protection.

This manual establishes Army doctrine for operations in a nuclear environment and details the doctrine for integrating nuclear considerations into all other aspects of the battlefield. It also describes the Army's role in nominating targets at corps and above levels and protecting the force from the effects of nuclear weapons detonation.

Nuclear operations may occur at strategic, operational, and tactical levels of war. Nuclear employment in a theater of operations has theater strategic, operational, and tactical results; execution has national strategic implications. The corps' role is to function at either the tactical or operational levels of war. At the tactical level, the corps accomplishes missions as Field Manual (FM) 100-15 describes. At the operational level, when directed and augmented, the corps functions as either the Army force (ARFOR), the joint force land component command (JFLCC), or a joint task force (JTF). By viewing the corps in its many possible roles, the reader can also discern nuclear procedures for echelons above corps (EAC) and joint missions.

This manual can help educate and train commanders and staffs at corps and operational levels in nuclear operations and educate and train divisions in nuclear force protection. It is used with Joint Publications (JP) 3-12.1, 3 -12.2 (SRD), or 3-12.3, and serves as the bridge between joint and

## DETERRENCE

Although the US military force's overriding mission is to deter war, especially nuclear war, the intent behind the 1991 Presidential Nuclear Initiative (PNI) was to enhance national security through arms reduction while preserving the capability to regenerate selected forces if required. Recent arms control agreements and unilateral initiatives provide for real reductions in the arsenals of nuclear powers. However, even with the most optimistic outlook, the sheer number of remaining weapons is formidable. An increasing number of potentially hostile states are developing or have the capability to develop weapons of mass destruction. Therefore, the US must maintain a modem, reliable, and fully capable strategic deterrent as its number one defense priority.

Deterrence is the product of a nation's military capabilities and that nation's willingness to use those capabilities. The US' policy is to terminate conflict at the lowest possible level of violence consistent with national and allied interests. The ability to conduct operational- and tactical-level nuclear activities enhances US deterrent policy.

The potential employment of nuclear weapons at theater level, when combined with the means and resolve to use them, makes the prospects of conflict more dangerous and the outcome more difficult to predict. The US' position is that it can achieve deterrence if any potential enemy believes the outcome of nuclear war to be so uncertain, and the conflict so debilitating, that he will have no incentive to initiate a nuclear attack. The resulting uncertainty reduces a potential aggressor's willingness to risk escalation by initiating conflict.

At the same time, a credible defensive capability, which would include the threat of employing nuclear weapons, could bolster the resolve of allies to resist an adversary's attempts at political coercion. For example, the US' capability of responding to biological and chemical attacks with nuclear weapons would likely reduce or eliminate such attacks.

Nuclear weapons contribute to but do not by themselves ensure deterrence. To have a credible nuclear deterrent requires a nation to have the means, the ability, and the will to employ nuclear weapons. The nation must also have—

- A reliable warning system.
- A modern nuclear force.
- The capability and flexibility to support a spectrum of response options.
- A deployable defensive system for theater protection.

The threat of nuclear escalation is a major concern in any military operation involving the armies of nuclear powers. Controlling escalation is essential to limiting a rational threat's incentive for nuclear response. Escalation control involves a careful selection of options to convey to the enemy that, although the US is capable of escalating operations to a higher level, it has deliberately withheld strikes.

The US views restraint in the use of nuclear weapons as an important way to control the escalation of warfare. Restraint provides leverage for a negotiated termination of military operations. However, the US cannot assume a potential enemy will view restraint in the same way, or that he will not employ weapons of mass destruction. Therefore, the US must be capable of deploying those forces necessary to defeat aggression, provide coercion, and bring the war to a speedy termination on terms favorable to the US and its allies. Commanders and staffs at all levels must continue to be familiar with nuclear-weapons effects, the actions required to minimize such effects, and the risks associated with using nuclear weapons.

## THE THREAT

The Cold War era's definitive threats to American security were nuclear surprise attack and the possible invasion of Western Europe. The new threat is worldwide regional instability (including the possible regional use of nuclear weapons) coupled with the proliferation of weapons of mass destruction.

Developing countries as well as regional powers are gaining the ability to manufacture nuclear arsenals. The current threat from developing nations primarily consists of short- and intermediate-range ballistic and cruise missiles and aircraft capable of carrying nuclear weapons and other weapons of mass destruction. Other threats, such as terrorists groups, may also possess nuclear weapons.

A nation that has the capability of using ballistic or cruise missiles and high-speed aircraft to deliver weapons of mass destruction at extended ranges

significantly increases those weapons' effectiveness as instruments of terror. Such capability also enhances the possibility of conflict escalation beyond a hostile region's boundaries.

The use of, or the threat of using, weapons of mass destruction within a campaign or major operation can cause large-scale shifts in objectives, phases, and courses of action (COA). Nuclear weapons make it possible to drastically change the effective ratio of regional forces and equipment and to create conditions favorable to a threat's operations. Consequently, if a potential adversary is not successful conventionally, he might consider using weapons of mass destruction.

The most accepted enemy employment methodology to destroy critical targets is surprise. A potential enemy might try to destroy massed units and all other critical targets using various nuclear-weapons burst options (space bursts, air bursts, surface bursts, below-surface bursts). Such attacks might be single attacks or part of a group of massed nuclear strikes. Therefore, retaliation or escalation would result in the likelihood of nuclear use against friendly forces. Or, retaliation or escalation could be used in response to an enemy's first use of weapons of mass destruction.

One element of the commander's critical information requirements (CCIR) is determining if the theater threat is capable of using weapons of mass destruction. The answer dictates future command actions.

## PROLIFERATION, NONPROLIFERATION, AND COUNTERPROLIFERATION

Proliferation is the process by which one nation after another comes into the possession of or attains the right to determine the employment of nuclear weapons, each potentially able to launch a nuclear attack upon another nation. Nonproliferation efforts focus on preventing the spread of missiles and weapons of mass destruction through arms and export controls beyond the scope of corps and EAC interest. Counterproliferation strategy focuses on military measures centering both on how to deter or discourage as well as how to defend and attack against the possible use of such weapons.

The Department of Defense's (DOD) counterproliferation initiative recognizes the goal of preventing proliferation of weapons of mass destruction and their associated delivery systems. It also recognizes that the US must continue to expand its efforts to protect forces, interests, and allies. The initiative has two fundamental goals:

- To strengthen DOD's contribution to governmentwide efforts to prevent, or diplomatically reverse, the acquisition of weapons of mass destruction.
- To protect US interests and forces (as those of its allies) from WMD effects by assuring that US forces have the equipment, doctrine, and intelligence needed to confront, if necessary, any future opponent who possesses weapons of mass destruction.

The Department of Defense marshals its unique technical, military, and intelligence expertise—

- To improve arms control compliance.
- To control exports.
- To inspect and monitor the movement of nuclear materials.
- To interdict shipments for inspection during crises.
- To strengthen the norms and incentives against WMD acquisition.

The Department of Defense's acquisition strategy in the areas of command, control, communications, and intelligence ($C^3I$), counterforce operations, active defense, and passive defense address the following critical counterproliferation challenges:

- Detecting and destroying WMD capabilities from production through storage to deployment.
- Conducting military operations in a WMD environment.
- Dealing with consequences of WMD use, including medical treatment, clean-up, and recovery.
- Coping with the diffusion of new technologies.

NOTE: This manual concerns the nuclear part of weapons of mass destruction.

Although nuclear weapons are an element of deterrence, potential regional adversaries might or might not understand the deterrence value of the

US' nuclear weapons. If the goals of promoting peace, deterring war, and resolving conflicts fail, deterrence fails. Therefore, fighting and terminating hostilities become paramount. United States doctrine assumes that if the potential foe is capable of using weapons of mass destruction, then US forces must act accordingly.

## NUCLEAR FORCES

Nuclear-capable forces (Navy and Air Force) are instruments of national power in regional conflicts. They contribute to theater deterrence or provide a war-fighting option to the NCA.

Because the Army no longer has an organic nuclear capability, the Navy or Air Force will provide nuclear support. The Army can now only nominate nuclear targets, usually at no lower than the corps level. The division normally is limited to NBC protection activities.

The capability of the US to deploy nuclear forces into a theater significantly complicates the enemy's planning process. The alert status of nuclear forces is a function of the world situation at any given time and, thus, enhances their responsiveness.

## LEADERSHIP

Battlefield stress in a nuclear environment will be higher than US forces have ever experienced. Only disciplined, well-trained, and physically fit units can function well in such an environment. Commanders who understand this and who provide soldiers with strong, positive leadership; good mental and physical preparation; and clear, comprehensive plans will ensure soldiers are in a better position to survive and win.

Units may have to operate with reduced mutual support and fire support, with degraded electronic communications abilities along extended lines of communications (LOC), and possibly without centralized control or continuous communications. Therefore, to improve command and control ($C^2$) leaders must work toward three general goals (which take on added importance in nuclear operations):

1. Instill an aggressiveness in their units that will transcend the shock and stress of the nuclear environment.
2. Train junior leaders to think and operate independently.
3. Develop small-unit cohesion.

Commanders and staffs must fully understand the potential of nuclear-weapons use by both an adversary and by a US joint force. They must also have a working knowledge of—

- Nuclear-weapons effects.
- Employment doctrine.
- Survivability measures necessary to preserve combat power.
- Medical requirements as a result of a nuclear explosion.
- The psychological impact of nuclear warfare on soldiers and units.

As commanders plan and fight successive battles involving actual or possible nuclear operations, they must continually assess their soldiers' psychological and physiological stresses. Commanders must emphasize situations in training, exercises, and leadership which will help soldiers accomplish their missions.

## TRAINING

On a nuclear battlefield every soldier will confront new and strange circumstances and be under constant danger of attack. Nuclear weapons will quickly cause many casualties as well as intermediate and long-term radiation effects. Soldiers will be exposed to death and destruction of a magnitude far beyond imagination and may have to operate in widely dispersed, isolated, and semiindependent groups. Everyone must understand and practice survival and mitigation techniques. Such techniques will give soldiers direction and confidence in a confusing, frightening situation.

The large and sudden losses that a nuclear attack will cause will shock and confuse inadequately trained or psychologically unprepared troops. Reaction times will be slower, and the ability to respond to leadership and the desire to perform at peak proficiency may be degraded. The violence, stress, and confusion can easily divert attention from battlefield objectives. Extraordinary discipline and leadership are vital to overcoming distractions,

maintaining the mission's focus, and pressing the fight.

Training, the cornerstone of success, technically and psychologically prepares soldiers for the nuclear environment. Successful nuclear operations require expanded combat training that includes—

- Mitigation techniques against nuclear effects.
- Radiation monitoring.
- Decontamination techniques.
- Operations exploiting nuclear-weapons use.
- Recovering and regrouping after an attack.
- Handling mass casualties.
- Having to use degraded resources to accomplish the mission.
- Nominating nuclear targets.

Soldiers will fight as well or as poorly as they have been trained. Clear, concise policies and guidelines provide control and direction. Commanders must emphasize the fact that aggressive maneuver, even by relatively small units, will have a high probability of success in the confused aftermath of a nuclear attack.

NOTE: See FM 25-50 for in-depth discussions of these topics.

## SUMMARY

This chapter describes the transition of joint nuclear doctrine to Army-oriented nuclear doctrine. A nuclear environment exists if either adversary in the conflict possesses nuclear capabilities. The levels of war clarify simultaneous activities Army forces conduct in the theater. Each level supports the next higher level of war.

The overall mission of military forces is to deter war—especially nuclear war. If deterrence fails, the US must be capable of deploying the forces necessary to defeat aggression, provide cohesion, and bring war to a speedy termination on terms favorable to the US and its allies.

The threat is worldwide regional instability (including possible use of nuclear weapons) coupled with the proliferation of weapons of mass destruction. Proliferation occurs when nations acquire and have the ability to use nuclear weapons against another nation. Nonproliferation activities attempt to prevent the spread of weapons of mass destruction. Counterproliferation centers on how to deter, defend, and attack against possible use of nuclear weapons.

In the event of either friendly or enemy nuclear-weapons use, commanders must provide soldiers with strong positive leadership, good mental and physical preparedness, and clear comprehensive plans. Positive leadership will ensure soldiers survive and win. Training is the cornerstone for success.

### Enemy

Anticipating and planning against the effects of enemy nuclear-weapons use against friendly forces is critical to campaign design. Commanders must ask, "Does the enemy have nuclear capability?" If the answer is no, the question is moot. If the answer is yes, commanders must address issues such as dispersion, type, yield, delivery means, availability of weapons, doctrine, tactics, and the likelihood of use.

### Troops

The number and type of troops available could greatly affect the tactical plan. Nuclear weapons can rapidly and decisively enhance combat power. Smaller forces possessing nuclear weapons can accomplish the mission of larger forces not possessing nuclear weapons. The unit's RES determines its fitness for duty. The lower the RES, the healthier the soldiers.

NOTE: See FM 3-3-1.

### Terrain and Weather

Terrain and weather can affect nuclear-weapons operations and influence offensive maneuver. For example, tree blowdown in a heavily forested area would obstruct the forward movement of friendly forces.

Normally, tactical fallout will not be significant in a low air burst. However, weather conditions could cause rainout in the area of operations. Therefore, if rain or snow falls through a nuclear cloud, significant tactical fallout may occur. Rain and fog can also lessen the blast wave as it travels through dense air.

### Time Available

Offensive actions become harder to conduct when the enemy has had time to organize his defense. The friendly commander can nominate nuclear weapons to effect surprise, prolong confusion, and sustain disorganization. Conversely, the nomination process can erode friendly units' available time because of the necessity of having to relay information and requests up through the chain of command and back down again.

## CONDUCTING OFFENSIVE OPERATIONS

The commander plans and coordinates force movement in detail to avoid confusion and delay and to gain surprise. He concentrates his forces quickly, making maximum use of cover and concealment, signal security, and deception while avoiding or masking actions that would alert the enemy to the coming attack. He then conducts the attack rapidly and violently with concentrated firepower to disrupt enemy positions and hit deep in the enemy rear. Nuclear weapons can enhance and support such plans by providing—

- Destructive firepower. Nuclear weapons, even when limited, can help friendly forces cause great destruction of enemy positions with a minimum concentration of forces.
- Surprise. Because delivery of nuclear fires requires little visible unit preparation, surprise can be complete. However, OPSEC within the stockpile-to-target sequence is essential. Forces must avoid a great display of preparation before nuclear strikes to prevent the loss of surprise.
- Shock. Nuclear-weapons use disorganizes, demoralizes, and freezes enemy forces in place. However, these effects will only be temporary; exploitation must be immediate.
- Flexibility. As maneuver forces develop the situation, the commander can nominate nuclear weapons to develop a major operation. He might also substitute nuclear weapons for maneuver forces, allowing a smaller force to succeed in its attack against a stronger force.
- Obstacles. A nuclear weapon can alter terrain to create obstacles such as fallen trees, fires, craters, rubble, and radiation. This nearly instant creation of massive obstacles will allow a smaller force to succeed where a larger force might ordinarily be required. Creation of obstacles slows and canalizes counterattacks and denies terrain to the threat. But, like shock and surprise, obstacles are temporary. Conversely, obstacles can impede forward maneuver if the commander has not considered least-separation distances.

Nuclear weapons can provide the commander with a unique advantage. However, he equally

| | |
|---|---|
| 100-15 | *Corps Operations.* This manual contains operational-level doctrine to corps commanders and staffs. |
| 100-16 | *Army Operational Support.* |
| 100-17 | *Mobilization, Deployment, Redeployment, Demobilization.* |

### Joint Publications (JP)

| | |
|---|---|
| 1-02 | *Department of Defense Dictionary of Military and Associated Terms.* |
| 3-12 | *Doctrine for Joint Nuclear Operations.* This publication sets forth doctrine for the combatant commander to use for the conduct of joint nuclear operations. It guides the joint planning and employment of US nuclear forces. |
| 3-12.1 | *Doctrine for Joint Nonstrategic Nuclear Weapons Employment.* This publication provides guidance for nuclear-weapons employment. Doctrine and guidance apply to the commander of combatant commands, subordinate unified commands, joint task forces, and subordinate components of these commands. |
| 3-12.2 (SRD) | *Nuclear Weapons Employment and Effects Data* (U). This publication sets forth doctrine and selected TTP for joint operations and training. It is the accepted joint standard for nuclear target analysis, employment procedures, and the source for nuclear effects data. |
| 3-12.3 | *Nuclear Weapons Employment and Effects Data.* |

### Department of Defense Nuclear Agency Effects Manuals (DNA EM)

1 (SRD) Chapter 10 Electromagnetic Pulse.

| | |
|---|---|
| Chapter 14 | Effects of Personnel. |
| Chapter 15 | Damage to Structures. |
| Chapter 17 | Damage to Military Field Equipment. |
| Chapter 21 | Damage to Missiles. |

NOTE: DNA is now known as the Defense Special Weapons Agency (DWA).

## RELATED PUBLICATIONS

Related publications are sources of additional information. They are not required in order to understand this publication.

### Allied Tactical Publications (ATP)

| | |
|---|---|
| 35A | *Land Force Tactical Doctrine.* This publication establishes common NATO doctrine for the use of land force commanders in military operations when NATO forces are placed under their command. |

# SOVIET MILITARY POWER

1986

# SOVIET MILITARY POWER

| | |
|---|---|
| First Edition | September 1981 |
| Second Edition | March 1983 |
| Third Edition | April 1984 |
| Fourth Edition | April 1985 |
| Fifth Edition | March 1986 |

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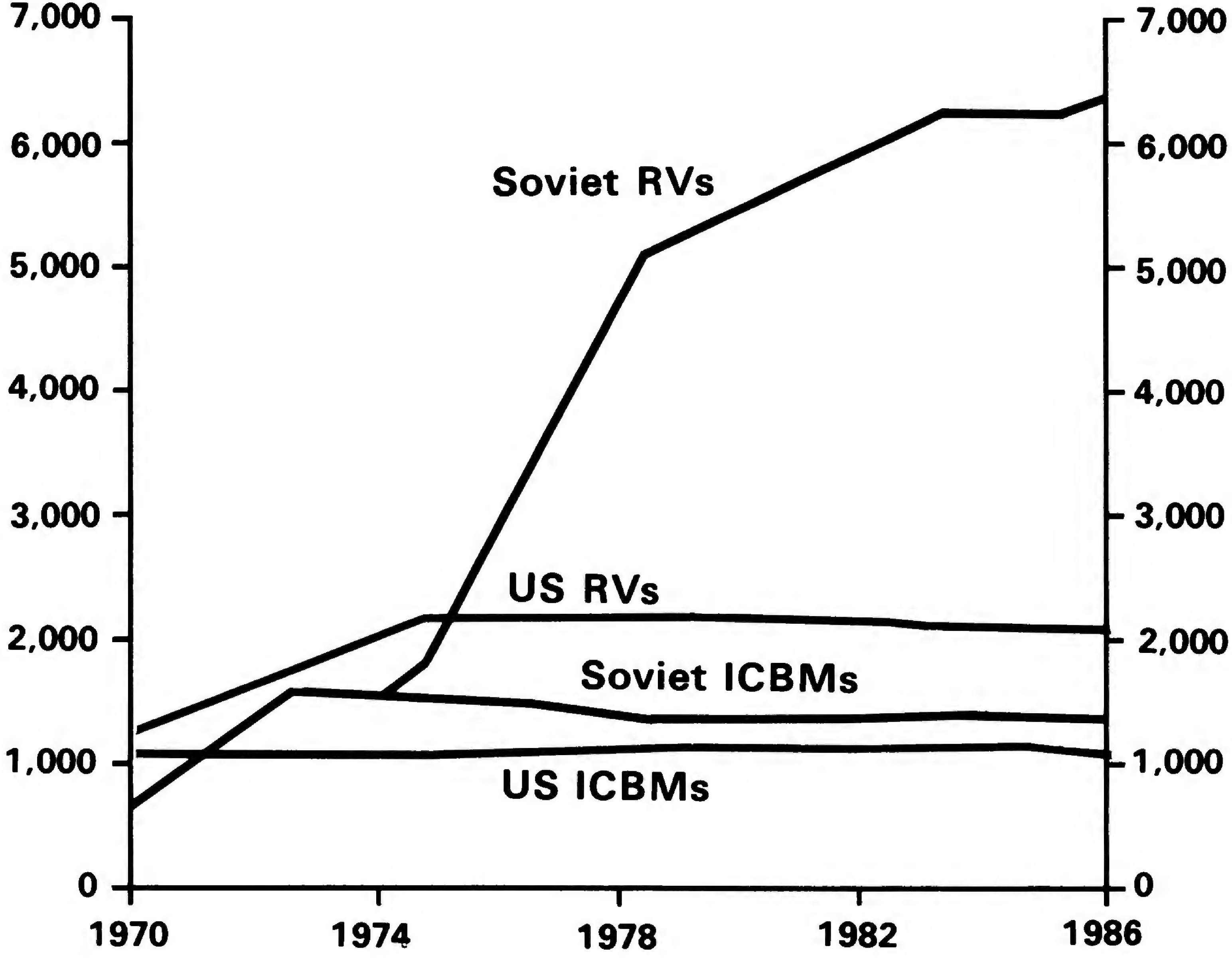
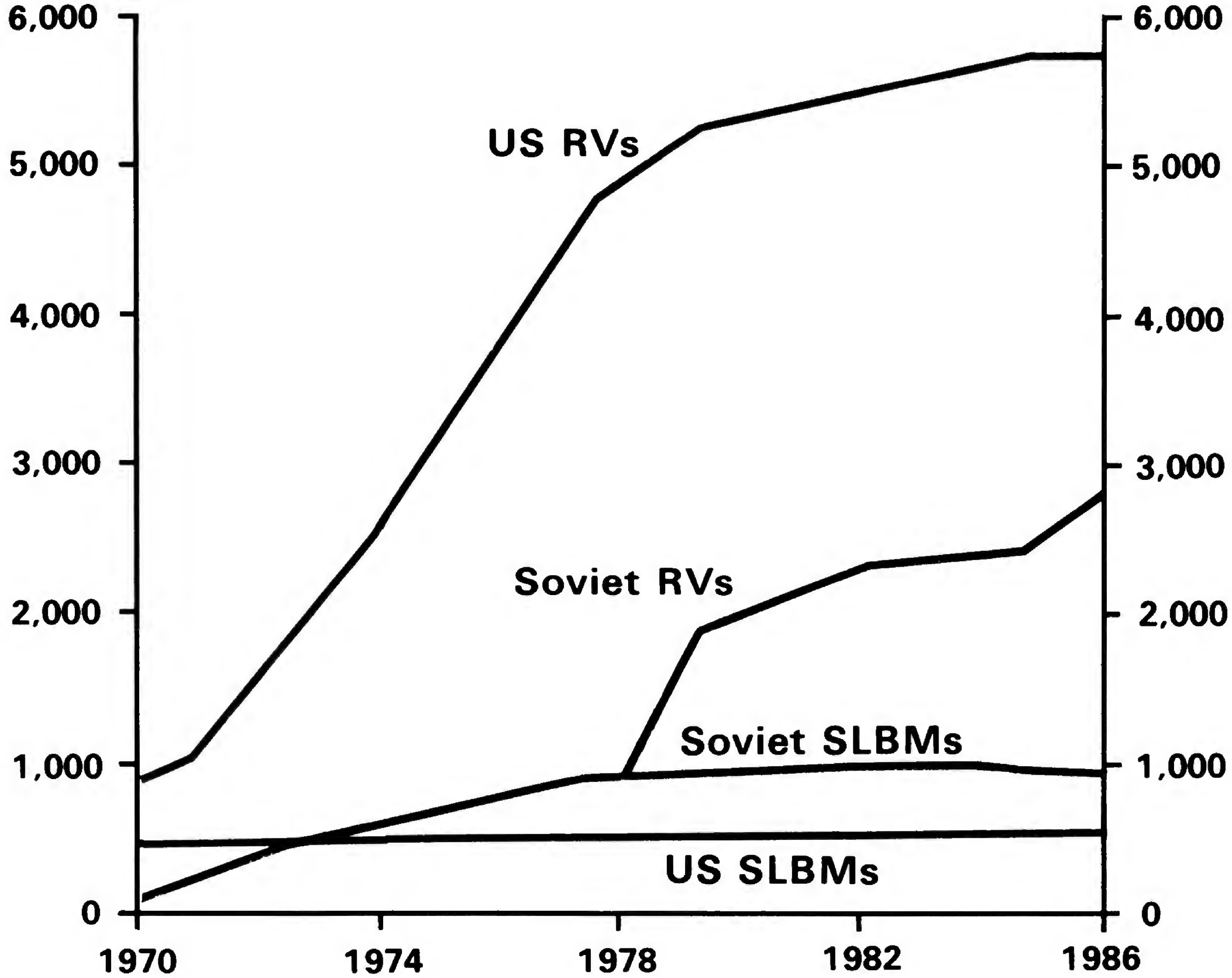
Printing Office, Washington DC 20402

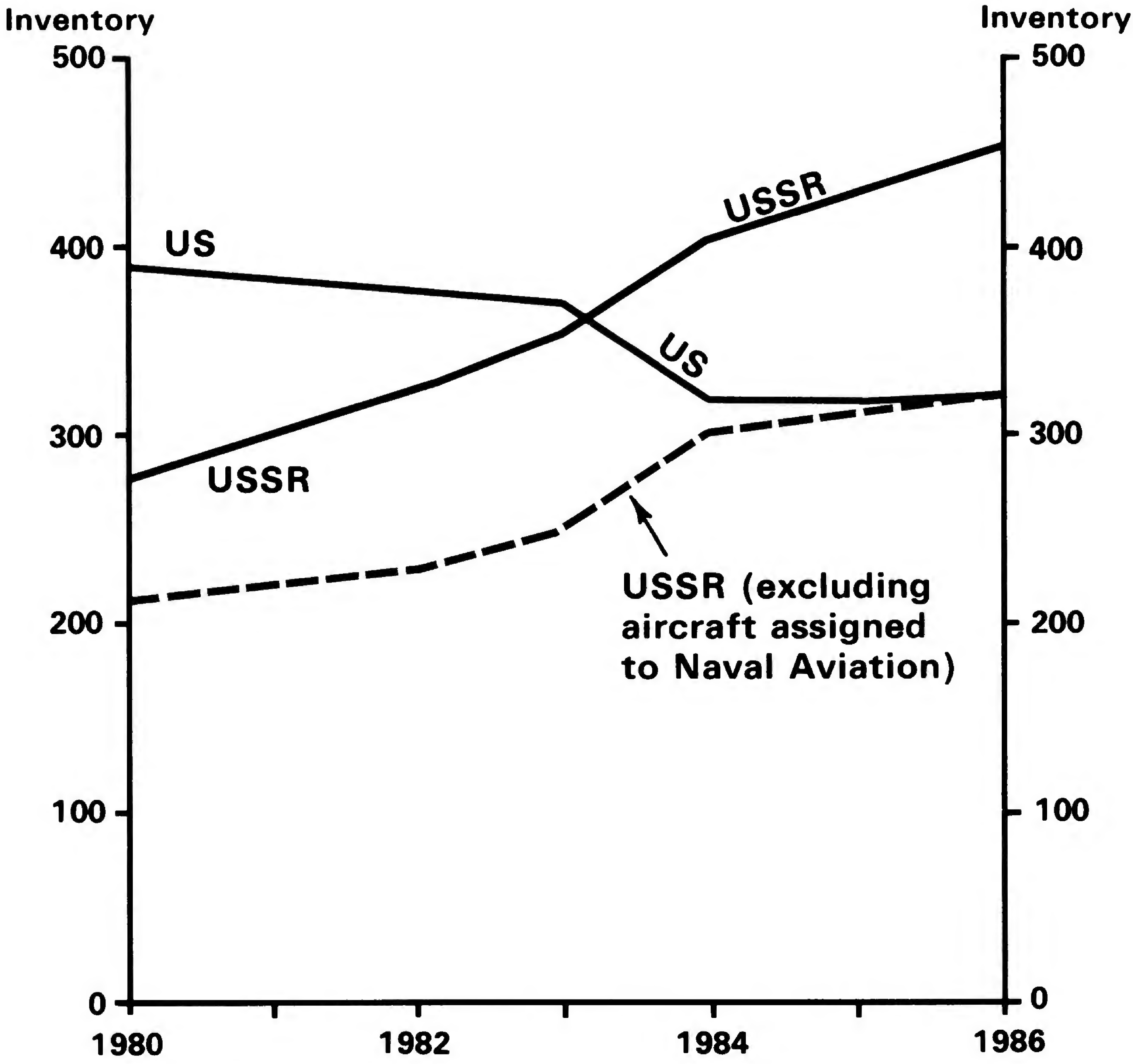
## US and Soviet ICBM Launcher and Reentry Vehicle (RV) Deployment 1970-1986



## *US and Soviet SLBM Launcher and Reentry Vehicle (RV) Deployment 1970-1986*

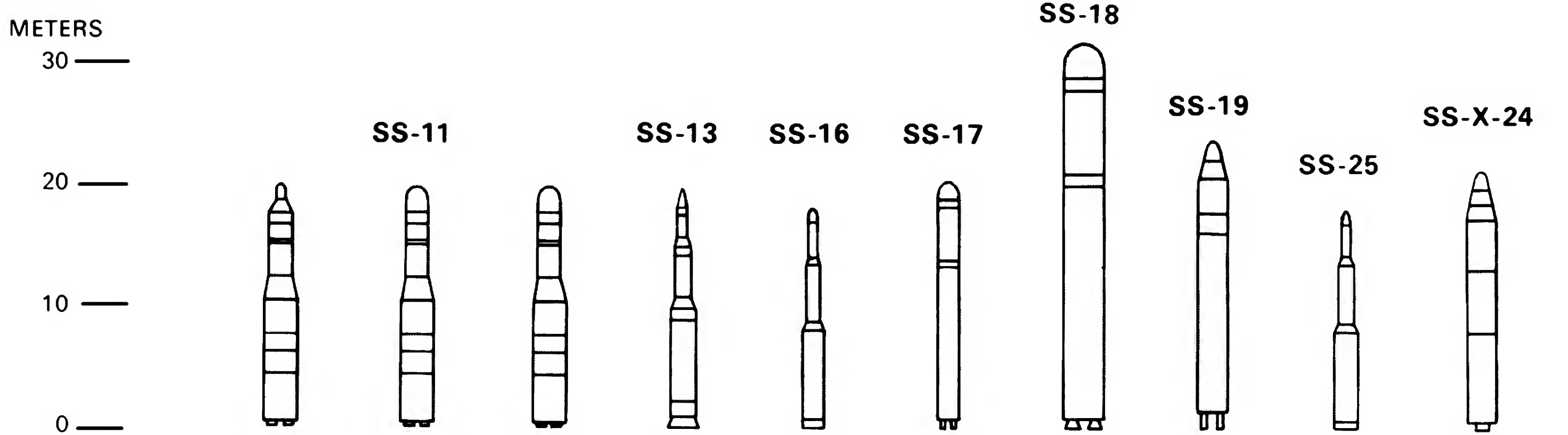


## *US and Soviet Intercontinental-Capable Bombers*[1]




[1] US forces include B-52, FB-111, and B-1B; Soviet forces include BEAR, BISON, and BACKFIRE.

## *USSR ICBMs*




| | SS-11 MOD 1 | SS-11 MOD 2 | SS-11 MOD 3 | SS-13 MOD 2 | SS-16 | SS-17 MOD 3 | SS-18 MOD 4 | SS-19 MOD 3 | SS-25 | SS-X-24 |
|---|---|---|---|---|---|---|---|---|---|---|
| NUMBER DEPLOYED | 28 | 420 | | 60 | Undetermined | 150 | 308 | 360 | 70* | In Development/ Testing |
| WARHEADS | 1 | 1 | 3 MRVs | 1 | 1 | 4 MIRVs | 10* MIRVs | 6 MIRVs | 1 | Up to 10 MIRVs |
| MAX RANGE (KM) | 11,000 | 13,000 | 10,600 | 9,400 | 9,000 | 10,000 | 11,000 | 10,000 | 10,500 | 10,000 |
| LAUNCH MODE | Hot | Hot | Hot | Hot | Cold | Cold | Cold | Hot | Cold | Cold |

## *US ICBMs*


| | TITAN II | MINUTEMAN II | MINUTEMAN III | PEACEKEEPER |
|---|---|---|---|---|
| NUMBER DEPLOYED | 17* | 450 | 550 | In Development |
| WARHEADS | 1 | 1 | 3 | Up to 10 |
| MAX RANGE (KM) | 12,000 | 12,500 | 11,000* | 11,000* |
| LAUNCH MODE | Hot | Hot | Hot | Cold |

* As of early 1986